UNIVERSITY OF SUSSEX

Performing Science: New Physics and Contemporary British and American Science Plays

Thesis Submitted for DPhil in English

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I hereby declare that this thesis has not been and will not be submitted in whole or in print to another University for the award of any other degree.

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SUMMARY

The present study uses the science of new physics (relativity theory and quantum mechanics) to construct a rigorous framework for analyzing the phenomenon of 'science plays', and as a means of exploring the implications that the new physics has for understanding theatrical representations. Basic facets of relativity theory and quantum mechanics are explained and used to develop an interdisciplinary approach to analyze the contemporary wave of science playwriting in Britain and America, the two cultures that have predominated in the tradition of science plays during the last three decades. Using a new approach to contemporary theatre, this study bridges the divide that still persists between science and the humanities by suggesting a new area where they intersect.

Seeking to provide an analysis of different understandings of science plays, this study also critically examines classifications used by science, theatre, and performance scholars, and offers alternative categories that allow this genre to be viewed in a different light.

This is the first study of its kind that furnishes a framework for the analysis of contemporary British and American science plays based on the theories of relativity and quantum mechanics. As such, the current study provides a coherent methodology that can be applied to a wide range of post-war science plays. Furthermore, it provides an in-depth analysis of a number of science plays, including *Oxygen*, *After Darwin*, *W;t*, *An Experiment with an Air Pump*, *Mnemonic* and *A Disappearing Number* within the context of new physics.

For my parents

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since the first day of my life, and Roham and Sadri whom I cannot imagine life without. I consider myself the luckiest in the world to always have you behind me, happy and strong.

Introduction

The present study aims at eliminating the well-known confrontation of the 'two cultures' defined by C. P. Snow in his 1959 lecture and book, *Two Cultures and the Scientific Revolution*, by using new physics (relativity theory and quantum mechanics) as an original framework within which to analyze British and American science plays written or first performed since 1990. This discussion functions on two levels: it initially provides a critical understanding of the genre of the science play by providing a new taxonomy; it then analyzes selected science plays – both text-based and performance-based – with reference to the new perception of reality publicized by new physics. There is a significant body of books and articles about science plays that have investigated the phenomenon in an attempt to define the genre and place it in context. This study aims to contribute to this field the first full-length analysis of science plays as a genre, within a framework other than itself (new physics), when most of the attention that has been given to the genre has focused almost exclusively on defining and contextualizing it.

This study was originally intended to investigate the ways in which the science plays that are about quantum physics and its practitioners have addressed science on stage. In the course of the research, both the quantum and non-quantum plays began to exhibit a set of similarities that could be only explained within the framework of new physics: similar to electrons in the subatomic realm, their narrative structures go through periodic quantum leaps; their characters and events are instantly connected across time and space, similar to entangled particles; they exhibit a Janus face, as if they are electrons with two opposing behaviors, both particles and waves; and they refuse specific solutions and tight closures in the same way that electrons refuse to be observed

as fixtures. It seemed that science plays, regardless of the scientific ideas they addressed, had responded to an understanding of external reality as fundamentally changed by quantum mechanics. The decision was made to use the five main principles of quantum mechanics (quantum leaps, the complementarity principle, entanglement theory, the observer effect, and the uncertainty principle) to construct a new paradigm within which to examine the genre of the science play.

In the initial proposal, it was not intended to include relativity theory in the investigation of science plays. However, the science plays' treatment of time and space as relative and interrelated, and the crucial part that the theory played in discussion of this genre with reference to quantum principles, resulted in relativity theory being assigned its respective position in the paradigm. Moreover, no study of the redefinition of reality at the intersection of twentieth-century physics and theatre can prove authority or academic reliability without reference to relativity theory, which launched an attack on classical physics' worldview by changing our understanding of the nature of time and space. Therefore the decision was made to change the analysis framework from quantum mechanics to new physics.

To illustrate the way reality has altered at the intersection of new physics and science plays is necessarily a matter of selection and interpretation. It is to construct a set of parameters and to invent a focus point. The paradigm proposed in this study suggests that new physics and science plays join in perceiving the external world and the human relation to it as relative, discontinuous, oppositional, nonlocal, subjective, and uncertain. Each of these terms reflects one of the main principles in new physics and a discussion of their connections and similarities forms the basis of this study.

New Physics and Science Plays

For millennia, the scientific paradigms within which nature operates have injected new perceptions of reality into the imaginary of western theatre. Aristotelian theatre has always embodied the basic assumption in physics according to which things that exist, by nature, contain within themselves "a principle of motion and rest" (Kelsey 44). "As for Aristotle", Johnson argues, "both tragedy and comedy are in their general conception modes of imitation where the imitation is produced by rhythm, language, or 'harmony', and the objects of imitation are men in action… it follows that tragedy and comedy should display that same motion" (2). This view of nature formed what according to Aristotle were the desirable elements of dramatic arts.

In the seventeenth century, the formulation of Newtonian physics with its version of reality as ordered by certainty, continuity, objectivity, and absolute space and time led into the formation of naturalism and realism in theatre, where playwrights and theatre practitioners, as detached observers, tried to depict the objectively real onstage. Their aim was to achieve the attainable certainty that physics had projected in its investigations into a nature with absolutely deterministic and identifiable relations between its components (Strehle 16).

With the formulation of the theory of relativity and quantum mechanics in the twentieth century, a changed understanding emerged that revolutionized previous concepts of reality for thinkers in every field, including theatre. For playwrights and theatre practitioners, external reality as they knew it, with absolute mathematical time and space, was now relative to the observer's motion and perspective. Reality at its most basic level, at the subatomic realm, was no longer governed by continuity, causality, objectivity, and certainty. Rather, it was nonlinear, accidental, subjective, and probabilistic. This re-imagination of reality as implied by these terms inspired a new theatre to emerge and continue to emerge that produces a literature/art open to the

dynamic, energetic, and manifold relations that characterize the quantum universe; a theatre whose perception of reality is constituted by the uncomfortable non-realistic discoveries of new physics.

One profound impact of the quantum dismantlement of reality has been on 'science plays', plays and performances that engage with scientific ideas, issues, and forms of expression that are drawn from scientific models. For decades after the revolution that physics brought about in the twentieth century, this field has been a dominant source of inspiration for science playwrights and theatre practitioners.[1] Einstein, Bohr, Heisenberg, Oppenheimer, and Feynman have been among the most popular characters in science plays, and concepts such as the theory of relativity, quantum mechanics, and string theory have also been repeatedly used by artists and writers involved in this genre. Moreover, ever since the aftermath of the bombing of Hiroshima and Nagasaki, events that revealed the destructive potential of the field, the ethical and social aspects of scientific research, especially in physics, have become a hot topic onstage in post-war science plays. This impact has been so great that in 1999, Charles A. Carpenter devoted a whole book (*Dramatists and the Bomb: American and British Playwrights Confront the Nuclear Age, 1945-1964*) to exploring the ways in which playwrights reacted to the social, political, and cultural consequences of the science of quantum mechanics.

However, the impact of the twentieth-century revolution in physics on this genre is not limited to physics plays only. In fact, the majority of the science plays written after the relativity and quantum revolution, regardless of their level of direct engagement with physics and physicists, share certain critical features in their treatment

[1] In her list of science plays Shepherd-Barr lists 25 plays dealing with twentieth-century physics, which compared to other scientific theories has been the most popular with science playwrights and theatre practitioners. The list of science plays at the end of this thesis adds 25 plays to Shepherd-Barr's list.

of time and space, their narrative strategies, characters and events, plots, and dramaturgical techniques that lend themselves to an effective discussion within the context of the new physics. It seems that this genre, along with establishing concrete links with relativity theory and quantum mechanics via an explicit engagement with them, has embodied, through its form and content, the basic epistemological and ontological assumptions that they present.

Since the popularization of science plays after the huge commercial success of Michael Frayn's *Copenhagen* in 1998, there have been various attempts to define, contextualize, and categorize the genre based on the topics, means, and aims that it encompasses: Judith Kupferman in "Science in Theatre" (2003) attempts a taxonomy by solely focusing on the 'matter' of science plays; Carl Djerassi in "Contemporary 'Science-in-Theatre': A Rare Genre" (2002) draws distinctions between science plays based on how and how much they have used science; Kristen Shepherd-Barr in *Science on Stage: From Doctor Faustus to Copenhagen* (2006) prioritizes performativity in science plays and employs a performance-oriented approach towards them; and Eva-Sabine Zehelein's *Science: Dramatic: Science Plays in America and Great Britain 1990-2007* (2009) limits her taxonomy and contextualization of science plays to dramatic texts only by employing a drama study approach.

Among these taxonomies, the last three have introduced a debate over what should be the primary focus in the scholarly analysis of science plays: performative elements, literary merits, or the quality/quantity of the science presented?[2] This study aims at bridging the gap among these approaches and therefore resolving the dispute by introducing a new taxonomy and analytical framework that is based on text-based

[2] David Pasto in "The Ethics of the Postmodern Science Play" (2012), Andy Jordan in "Science-in-Theatre: A Significant New Genre?" (2013), and Mike Vanden Heuvel in "'The Acceptable Face of the Unintelligible': Intermediality and the Science Play" (2013) address this debate by pointing out the assets and difficulties of the approaches.

drama, performance, and the specific function of science in the plays.

Most of the critical responses to plays and performances that deal with scientific ideas and issues have focused almost exclusively on contextualizing them, elucidating their characteristics and ideas and their place within the debates over the two cultures. They, in other words, have either analyzed the genre within the context of itself or with reference to the dispute over the relationship between the sciences and humanities. In her article, Kupferrman recognizes the genre by explaining what thematic concerns are being addressed in them. Djerassi in "Contemporary Science-in-Theatre" introduces the term science-in-theatre and sets out its parameters. Shepherd-Barr in *Science on Stage* distinguishes different styles of science plays and explains the ways in which their theatricality and performativity enact scientific ideas on stage within a historical context covering the years from 1604 to 2005. Zehelein in *Science: Drama* first discusses the genre within the context of the disputes between the two cultures and then provides a sense of the variety of ways scientific ideas and personalities have featured in dramatic texts from 1990 to 2007. Science plays, however, reveal more than similarities and differences in thematization, modes for addressing science on stage, or the ability of the theatre to fuse the two cultures. They have responded to the events and ideas occurring in the larger field of discourse that emerged from interrelated thinking about reality in the twentieth-century physics and in theatre. Contemporary science playwrights and theatre practitioners do not respond to the same external conditions that their realistic ancestors did. They write and perform with reference to a changed external reality that has revealed contradiction, ambiguity, uncertainty, and duality. This transition requires a major rethinking in how we approach the genre and this is what this study intends to do. The scholarly aim of the present study is to provide the first full-length investigation of science plays within a framework that goes beyond the boundaries of the genre itself

or the discussion of the two cultures debate. It introduces new physics as a new framework within which to discuss the form and the content of science plays within the bigger discourse of new physics reality. Similar to the works discussed here, this study aims to contribute to further fruitful discourse in the field by taking the discussion one step further and investigates, defines, and contextualizes the genre using the quantum view of the universe that constitutes our current understanding of reality.

Most of the previous work involving new physics and theatre has attempted to create a new paradigm within which to discuss the theatrical performance per se or the practice of a particular practitioner with relation to new physics, particularly relativity theory and the observer effect. These studies[3] show how the implications of these theories (a redefined observer role, a multiple and indeterminate reality, and the creation of these realities by their own inhabitants) have affected the performer-spectator interaction and the actor-role relation, have created a more incorporeal expression of performance such as game-playing, improvisation, an interactive *mise en scène*, parataxis, and have made actors the sources of unpredictability, individuality, and difference. In these studies, the investigation of specific theatrical events takes place within the bigger picture of performance practice as examples that clarify the intersection between performance (as an approach) and new physics. The discussion of performance in this study is limited to the exploration of the ways in which quantum mechanics and relativity theory are embodied in the expressive forms of selected performance works and not the practice of performance per se.

The research questions in this study can be grouped in two categories. The first category is specific to the science play genre: are the previous taxonomic endeavors to

[3] See David E.R. George's "Quantum Theatre-Potential Theatre: A New Paradigm" (1989), Natalie Crohn Schmitt's *Actors and Onlookers* (1990), Michael Vaden Heuvel's "The Politics of the Paradigm: A Case Study in Chaos Theory" (1993), and Paul Johnson's *Quantum Theatre: Science and Contemporary Performance* (2012).

categorize and conceptualize science plays effective and exhaustive? If not, is there a better way to categorize them? The second category engages with new physics and contains the primary research question: if and in what ways new physics can be used to construct a theoretical framework within which to discuss science plays? This question encompasses the subsidiary questions: how far does this study suggest that the relationship between new physics and science plays gives rise to a new paradigm with which to represent a post-quantum reality? Are only plays that directly deal with new physics suitable to this analysis? If not, what features lend themselves to this approach? How can a study of the intersection between new physics and science plays fill in the gap between the sciences and the humanities?

Structural Links

The opening chapter provides a critical examination of previous categorizations of science plays in order to demonstrate their assets and difficulties, and introduces a new taxonomy. The chapter then explores the relationship between science and culture, and theatre in particular, and explains why theatre lends itself so well to the exploration of science, and what has made physics in general and new physics in particular a significant field to be explored in theatre. The major principles of relativity theory and quantum mechanics along with their implications are outlined, in contrast to Newtonian physics, and a comparison of realistic theatre and contemporary science plays is also provided.

Drawing on the overlaps between the implications of the new physics and science plays, Chapter 2 presents brief readings of a broad range of contemporary British and American examples of the genre within six areas of enquiry: nonlinear time

and space (relativity theory), discontinuous episodic narrative structure (quantum leaps), a doubled difference within the thematic content (complementarity), an instant connection between temporally and spatially distanced characters and events (theory of entanglement), and polyphony and open-endedness (observer effect and the uncertainty principle). The aim in this chapter is to set out the parameters for a more thorough analysis of the intersection between new physics and science plays in the subsequent chapters.

Chapters 3, 4, and 5 contain a series of case studies exploring a range of text-based and performance-based science plays in conjunction with the theories developed in Chapter 2. These chapters each focus on one of the categories provided in the taxonomy of science plays in Chapter 1. Each case study is discussed within two frames of analysis: that of new physics and that of the specific function of science in the play.

The study finishes with an up-to-date list of science plays written after 1990 in the United Kingdom and America (Appendix 3). In this list, science plays are also categorized according to the taxonomy provided in Chapter 1. In the case of those plays and performances that have not been published or have been performed once only, the information necessary for placing them in a category has been obtained either by directly contacting the playwright/theatre practitioner or by reading critical reviews of the plays or director's notes.

Critical Overview

Most of the plays discussed in this study do not engage with the new physics or its practitioners at a concrete level. The decision has been consciously made not to focus only on science plays that explicitly engage with the new physics. This decision enables

this study to test whether new physics can be used as an effective paradigm for the analysis of the science play in a more general sense, rather than with relation to those plays whose content is specifically influenced by the new physics.

The date of publication or premiere, the country of origin, the level of applicability, plot and theme, and recognition are the five criteria that have guided the selection of plays in this study. The timeframe is demarcated by the years 1990 and 2013, since during this period more science plays were produced than before. According to the very useful list of science plays and performance projects that Kirsten Shepherd-Barr provides in her book, between the years of 1604 and 1990, only 39 plays and performances about science were written and performed, whilst she lists 83 projects and plays for the period 1990 to 2005. Appendix 3 adds 56 plays and performances to her list, all produced between 1990 and 2016.

The major focus in this study is on British and American theatre, since these two cultures have been more successful compared to other cultures in producing plays and performances about science. Moreover, due to the author's unfamiliarity with other languages, and therefore to avoid the necessity of using translations, the decision was made to limit the scope of the study to the two cultures of Britain and America.

The aim of this study is not to comprehensively and exhaustively discuss all science plays within the context of new physics; rather, it is to provide a sense of how the new physics can formulate an effective theatrical paradigm for the exploration of science plays. The main criterion here for the selection of plays and performances is how effectively they lend themselves to discussion within the paradigm. At the same time, it seemed rewarding to sketch out the variety of scientific disciplines that this genre has engaged with by focusing on science plays that deal with different topics and scientists.

The key texts and performances examined in this study are Margaret Edson's *W;t* (1995), Shelagh Stephenson's *An Experiment with an Air Pump* (1998), Timberlake Wertenbaker's *After Darwin* (1998), Carl Djerassi and Ronald Hoffmann's *Oxygen* (2001), and Complicite's *Mnemonic* (1999) and *A Disappearing Number* (2007). The analyses of these individual plays serves as a model that can be expanded to the study of other science plays written after the discoveries of the new physics, and also provides new understandings of the plays in question. As a complement to these six plays, another 26 plays and performances are briefly explored within the paradigm of new physics, expanding the scope of its applicability to the genre even further. One of the selection criteria for these science plays has been the amount of critical attention they have received. There is a significant body of science plays that despite their theatrical and dramatic merits have been neglected by critics and scholars. Lesser-known science plays have therefore been chosen, some of which have been performed but not published (copies of the scripts were provided by the playwrights and directors).[4]

The two performance-based plays discussed in detail in this study are by the company Complicite; the reason being that (together with their high level of applicability) they were two of the very few performances available to watch on DVD.

A number of terms have been introduced to label plays/performances that deal with science or scientists, including science-in-theatre, science play, science-engaged plays/performances, and science, theatre, and performance. In this study, however, the decision is made to use the term science play, an umbrella term that is used both for text-based and performance-based plays. This is the term that the genre has been most known by in the last few decades, and it has been frequently used by the two leading

[4] This study would not have been possible without the help and permission of Robert Marc Friedman, Deborah Stein, Lauren Gunderson, Ira Hauptman, Matthew Wells, Bob Clyman, and David Egan to work on their plays/performances and to quote from them.

science play scholars, Shepherd-Barr and Zehelein. The terminology of the genre and what or how it should be named deserves a detailed scholarly analysis, which is outside the scope of this study. The phrase ‘science play practitioners’ is used in this study as an umbrella term to refer to both playwrights and theatre practitioners that deal with scientific ideas and issues.

It is true that a reliable work of scholarly research does not happen in isolation and this study has consulted the works of many thinkers and scholars where needed, and sometimes contradictory positions are taken. The theories and ideas presented here are not meant to be exclusive; in fact, as Johnson has rightly noticed, “It is necessary of the quantum mechanical scholar to attempt to hold contradictory opinions simultaneously” (9).

Chapter 1

Science, Theatre, and New Physics

1.1 The Categorization of Science Plays

Over the past three decades, the surge of new plays and performances that, in one way or another, deal with scientific subjects and ideas appears substantial enough to be termed a new phenomenon. *New York Times* critic Carol Rocamora suggested in 2000 that "Science is becoming the hottest topic in theatre today, so much so that it's identifiable as a millennial phenomenon on the English-speaking stage" (50). Onstage for four years in London, two years in Broadway, and performed in cities all over Europe and America, Michael Frayn's 1998 play *Copenhagen* stands at the heart of the proliferation of these plays known as science plays. When the New York production of *Copenhagen* won a Tony Award for best play in 2000, a new surge of interest was ignited amongst science play practitioners in writing about and staging issues around science. Theatre and literary scholars also began writing about the role of science in the theatre. In September 2000, for example, an entire issue of the journal *Interdisciplinary Science Reviews* was devoted to an exploration of new trends in science and theatre. In March 2000 a major convention was held in New York featuring leading figures from the two domains. And in April 2000, a month-long festival of works inspired by science was played at the Ensemble Studio Theatre in New York. The same year, Arthur Kopit's *Y2K* (1999), and David Auburn's *Proof* (2000) were staged at the Manhattan Theatre Club.

As well as the popularization of science plays, after the huge success of *Copenhagen*, the role of funding initiatives and financial supports in the rapid increase

of these plays should be mentioned. Since 1998, the Sloan Foundation in New York has encouraged playwrights to write in the field by sponsoring a festival of science-based plays. Since 2000, the Wellcome Trust in Great Britain has also solicited and funded new plays that revolve around scientific subjects. In September 2005 a three-day conference entitled 'Rules of Engagement' was sponsored by CNAP, a bioscience research center at the University of York, to explore the relationship between science and art through talks, performances, and debates. The cash awards offered by institutions such as the Science and Technology Facilities Council, established in 2006 in the United Kingdom, also encourage artists to be more active in the field. The general aim of such financial support and publicity is to get more people involved in the sciences and hence raise public awareness of scientific issues.[5]

Kirsten Shepherd-Barr discusses the large increase in the number of plays and theatre performances that engage with scientific issues in *Science on Stage*. The very useful list she provides of the science plays/performance projects in her appendix reflects how popular the subject of science has become in recent decades. Together with Shepherd-Barr, Eva-Sabine Zehelen, Judith Kupferman, and Andy Jordan in "Science-in-Theatre: A Significant New Genre?" (2013) have also noticed the vast increase of science-related plays and performances.

Science plays did not, however, spring up freshly born in 1998; for centuries, playwrights and theatre practitioners have adapted science as their subject and have had scientists as their protagonists. The Greek comedy *The Clouds*, written by Aristophanes in 423 BCE, is the first known example of a science-related play. Ironically enough, the first play in this genre is a satire of scientific speculation and the practitioners of

[5] For more information on the importance of familiarizing the general public with scientific discourses, see Bodmer, Walter. *The Public Understanding of Science*. London: Royal Society, 1985, and, Priest, Susan Horing. "Information Enquiry, Public Understanding of Science, and the Biotechnology Debate." *Journal of Communication* 45.1 (1995): 39-54.

science. Between 423 BCE and the late nineteenth century, few plays were written about science and scientists; some notable examples include Christopher Marlowe's *Doctor Faustus* (1604), Ben Jonson's *The Alchemist* (1610), Thomas Shadwell's *The Virtuoso* (1676), Henrik Ibsen's *An Enemy of the People* (1882), and George Bernard Shaw's *Doctor's Dilemma* (1906). Along with the rapid pace of scientific and technological advancements, the interest among playwrights and theatre practitioners in writing about/performing science also began to grow. By the mid-twentieth century many more science plays were written, at the heart of which stands Bertolt Brecht's *Life of Galileo* (1939, 1947). In the following decades, this interest continued its accumulation until the 1990s, which saw what Shepherd-Barr describes as an "explosion" of science plays (2).[6] As the list of science plays in Appendix 3 indicates, in Britain and America alone, more than 180 theatrical projects about science have been produced during the last three decades.

Science plays cover a very wide range of scientific disciplines, including physics, mathematics, chemistry, astronomy, genetics, psychology, medicine, and evolutionary theory. They also include different cultures, such as American,[7] British,[8] German,[9] French,[10] Irish,[11] and Canadian.[12] Some attempts have been made to identify

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[6] For a comprehensive list of science plays/performances written/performed between the mid-twentieth century and the 1990s, see Shepherd-Barr's appendix "Four Centuries of Science Plays: An Annotated List" in *Science on Stage: From Doctor Faustus to Copenhagen* (2006).

[7] See Appendix 3.

[8] See Appendix 3.

[9] See Rennert, H. "The Threat of the Invisible: The Portrait of the Physicists in Modern German Drama" *To Hold a Mirror to Nature: Dramatic Images and Reflections*. Ed. Karelisa Hartigan. Washington, D.C.: UP of America, 1982.

[10] Some of the examples are *Les Variations Darwin* (2004), A play produced as a collaboration between French neuroscientist Alain Prochiantz and theatre director Jean-Francois Peyret, John-Noel Fenwick's *Radiation* (1992), and *Les Palmes de Monsieur Schutz* (2002).

[11] Examples are Brian Friel's *Molly Sweeney* (1994) and Mick Gordon's and Paul Brok's *On Ego* (2005) and *On Emotion* (2008).

[12] Some of the examples are Maureen Hunter's *Transit of Venus* (1992), David Egan's *The Fly Bottle* (2004), Thiessen Vern's *Einstein's Gift* (2003). Other cultures have also produced science plays, such as Greece (Doxiadis Apostolos's *Incompleteness*: *A Play and a Theorem*

and classify science plays according to different categories. Judy Kupferman, lighting designer, theatre scholar and critic, divides science plays in terms of their thematic content: "Plays about the social implications of science, plays about scientists as people, and plays which center on science itself". The first category deals with the harms and benefits of science for society and the scientist's ethical responsibilities; the second encompasses plays that are about scientists and which aim to bring science as close as possible to their audience through inviting them to relate to the protagonist on stage; and the final category consists of those plays that enact the scientific idea with which they engage. The categorization proposed by Kupferman is very helpful, however it involves a great deal of overlap, which results in some plays belonging to more than one category. As Zehelein explains, with regards to Kupferman's first category, it is inevitable that the social implications of science will enter into the other two categories as well. If science as such or scientists as people are at the center of a dramatic work, then the social implications are likely to be inseparable from this (91).

An alternative categorization for science plays is suggested by the chemist-turned-playwright Carl Djerassi. In the 1990s Djerassi became concerned with the widening gulf between the sciences and the humanities, and the fact that scientists themselves had made very little attempt to communicate with other fields. He therefore decided to create a new genre through which to communicate, as a scientist, with a non-scientific, non-academic audience. In 1998 he embarked on a trilogy of plays (*An Immaculate Misconception* (1998), *ICSI* (2002), *Taboos* (2006)) and introduced a genre he labelled 'science-in-theatre', which he defined as follows:

> By this label [science-in-theater] I refer to plays in which science or scientists do not just fulfill a metaphoric function… In my plays, what I call the 'tribal practices' of scientists constitute the central focus of the drama, as, for instance, in

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(2004)), Puerto Rico (Allen Davis's *Red Pumps at Grand Zero* (2002)), and New Zealand (Stuart Hoar's *Rutherford* (2000)).

> Michael Frayn's *Copenhagen*. My concept of 'science-in-theater' requires that the science depicted be actual or at least plausible and that the conduct of my scientific characters be authentic documentations of professional behaviors. (*Sex*, viii)

Based on his definition of science-in-theatre, Djerassi criticizes many science plays that, according to other scholars, namely Shepherd-Barr, are the best examples of the genre, due to their having merged form and content (to be discussed shortly):

> There are canonical plays – admittedly few, but important ones, and written by famous playwrights – that have some scientific themes, yet I would not categorize them as 'science-in-theater' but rather as plays with some scientific content. Four examples should suffice: Brecht's *Life of Galileo*, Dürrenmatt's *The Physicists* and Stoppard's *Hapgood* and *Arcadia*. (*Science on Stage* 98)

What Djerassi categorizes as science-in-theatre is therefore a play in which science and scientists form the core and in which the facts are impeccably correct. What he puts the greatest emphasis on, in other words, is the quality of the science presented, rather than its literary or performative merit. Djerassi's perception of science-in-theatre will be discussed in more detail in Chapter 4.

A good summary of what Djerassi considers science-in-theatre is provided by Zehelein in *Science: Dramatic*. She explains that, according to Djerassi, a science-in-theatre play should have four distinctive features: "First, accurate description and representation of the scientific idea and theme, second, realistic depiction of the tribal culture of the scientists, third, a plot which is firmly rooted in the scientific topics and/or context, and finally, a didactic element" (14). She then defines Djerassi's science-in-theatre as an offshoot of the science play, a genre he describes as "a rainbow-colored umbrella term" (86). She explains that within this genre there are five different categories: 'Docere et Delectare', 'The Tribal Culture of the Scientists, Then and Now', 'History of Science in Theatre', 'Science to Play with', and 'Science as Fig Leaf'. The first category refers to those plays in which science is central and a scientific idea is

didactically taught; examples are Djerassi's *ICSI* and *Taboos*. The second category is about scientists as a community. These plays teach the audience "what characterizes the individual scientist and the scientists as a group, guide their thinking and behavior, make them tick, or what constitutes the underlying fascination of the scientific endeavor" (14); examples are *Oxygen*, *Proof*, Stephen Poliakoff's *Blinded by the Sun* (1996), and Peter Parnell's *QED* (2001). The third category consists of those plays which depict actual historical scientific incidents and scientists. Examples of this form are Marc Friedman's *Remembering Miss Meitner* (2002) and *Copenhagen*. Plays of the fourth category use science "for metaphorical and symbolical levels of meaning within a plot where scientific themes are part of a larger metaphorical spiel" (15). According to Zehelein, *Arcadia* (1993) seems to be unique in this form. The final category encompasses the plays that entail science or the name of a scientist in the title/plot without having the dramatic action focused on either of them and there is no symbolic or significant metaphorical usage of science to be identified. She concludes that these plays, depending on the "umbrella definition of the term", could be entirely excluded from the genre (14-15). Zehelein then provides her own definition of science plays, which raises an important issue:

> The single characteristic which binds all Science Plays together is their use of realistic or real science, in clear contrast to science fiction… It is of central importance to stress that Science Plays are text theater and not director's theater. They rely on the spoken word on stage, on dramatic dialogue, and not primarily on the bodily performance in order to convey meaning. (320)

Zehelein's emphasis on the quality of the science presented in the play as the most important factor clearly reflects Djerassi's view, but in her definition of science plays she prefers "classic formats that put the text at the centre" (80) to more modern performative formats. It is true that many of the best examples of science plays appear to be text-based; nevertheless, the majority of them also, as Jordan has rightly noticed,

"seek to synthesize textuality and theatricality" (8). Moreover, "Zehelein made these remarks in 2009", Jordan explains, "but the historical, intellectual and cultural scope of her book stopped in 2007" (9). Zehelein therefore fails to notice the growing interest in science among theatre practitioners. During the last decade, the number of devised and cross-disciplinary productions dealing with science has radically increased, and new theatre companies have emerged which only produce science-based performances. These companies are very much close to Djerassi's definition of science-in-theatre. They incorporate actual plausible science into the fabric of the performance and generally carry a didactic element. Their works are mostly the result of a close collaboration between scientists and theatre practitioners and testify to a brave attempt on the part of the scientists to bridge the divide between the two cultures and to bring science to a scientifically illiterate public. There are many examples of the collaboration between scientists and theatre practitioners, including the fourteen-year collaboration between Djerassi and theatre director Andy Jordan; Menagerie Theatre Company's long-time collaboration with playwright/zoologist Craig Baxter; Mick Gordon's collaboration with neuropsychologist Dr. Paul Broks in *On Ego* (2005) and *On Emotion* (2008); Clod Ensemble's work with doctors in the *Performing Medicine* (2007) project, which was designed to help medical students and doctors gain the necessary skills related to their clinical practice; Complicite's collaboration with mathematician Professor Marcus Du Sautoy in *A Disappearing Number*; Fuel Theatre's project on memory, *Autobiographer* (2012), produced in collaboration with psychologist Professor Sube Bannerjee, and *Body Pods* (2013), made in collaboration with hepatologist Professor Graham Foster; *Bloodlines* (2013) produced as a result of the collaboration between theatre director Alex Mermikides and clinical hematologist Ann Van de Velde; Unlimited Theatre's collaboration with physics professor Vlatko Verdal, cognitive

psychologist Denis McKeown, and neuroscientist Tim Griffiths on two projects, *The Ethics of Progress* (2012) and *The Noise* (2012); science-specialized theatre company Curious Directive's collaboration with a number of scientists[13] on projects from 2011 to 2014; the collaboration between Metta Theatre and six scientists[14] to produce *Mouthful* (2015); and Islington Community Theatre's collaboration with neuroscientist Sarah-Jayne Blackmore in *Brainstorm* (2015). Other theatre companies that have regularly produced science-based works include Third Angel (*Hurrysickness* (2004) and *A Perfect Circle and Technology* (2009)), Pit Collective (*A Stroke of Genius* (2009)), Reckless Sleepers (*Schrodinger's Box* (2009)), Fevered Sleep (*Written with Light* (2012) and *Stilled* (2012)), and the UK-based Russian theatre company Portable Palace.[15] These science-based performances clearly show that science plays can also be director's theatre.

The third categorization of science plays is suggested by Shepherd-Barr and revolves around the notion of theatricality and performativity. Shepherd-Barr argues that other categorizations, namely Kupferman's, cannot hold because "they fail to take theatricality into account" (4). She proposes another classification based on playwrights' biographies rather than the content of the plays. She argues that science plays come from four different sources: first, playwrights who have become interested in scientific issues, such as Stoppard, Frayn, Brecht, and Wertenbaker; second, scientists such as Carl Djerassi and Elizabeth Burns who are using the stage to convey scientific ideas to a general audience; third, science plays which were written during the time when documentary theatre was popular; and finally a new trend in science playwriting which

[13] The neuroscientist Chris Burgess, the myrmecologist Ferguson-Gow, the evolutionary biologist Simon Watt, the physicist Robert Howell, and the geneticist Kevin Moffat.
[14] Professors Tim Benton, Kamal Bawa, Suzanne Filteau, Ilkka Hanski, Molly Jahnand, and Tim Lang.
[15] Many of the performances and theatre companies listed here are taken from Andy Jordan's "Science-in-Theatre: A Significant New Genre?"

is based on collaboration between theatre directors and scientists. These plays are generally embedded in performance techniques rather than in literary texts: examples of such collaborations are Peter Brook and Marie-Helene Estinne, Luca Ronconi and John Barrow (4). The definition Shepherd-Barr offers of science plays recognizes this dramatic genre "from the perspective of drama and theatre, with an emphasis on performance" (3). This definition is to some extent similar to those of Djerassi and Zehelein but differs in an important aspect: "For my purposes, they [science plays] will be shown to share certain critical features: a casting of the scientist as hero or villain (or sometimes both), a direct engagement with 'real' scientific ideas, a complex ethical discussion, and an interdependence of form and content that often relies on performance to convey the science" (2).

For Djerassi and Zehelein the interdependence of form and content and the overemphasis on performativity in Shepherd-Barr's definition is very problematic as it suggests that it is the performativity of a science play rather than its textuality that conveys the scientific idea. What Shepherd-Barr recognizes as "a certain critical feature" of science plays – "to literally enact the idea that they engage" (Shepherd-Barr 6) – is not considered important in Djerassi and Zehelein's definitions. Shepherd-Barr claims that "Later science plays – the ones that define the new wave of science playwriting in the 1990s and beyond – move toward a formal and structural integration of the science" (16), and concludes that "it is not the quantity of the science in a science play that matters, but the quality of its integration: the way in which it figures both thematically and theatrically" (19).

The emphasis that Shepherd-Barr places on performativity in the genre impels Djerassi to accuse her definition of containing a great deal of bias (*Science on Stage* 96). However, Shepherd-Barr's definition appears to be much less biased than

Djerassi's; unlike the latter, who totally excludes plays that do not correspond to his concept of science-in-theatre from the genre ("Science on Stage" 98), Shepherd-Barr excludes plays that do not enact the idea that they engage from the category of 'good' science plays (6). Nevertheless, her definition is also to some extent restricted. Most of the plays that are excluded from Shepherd-Barr's category of 'good' science plays, due to their lack of performativity, have gained significant international recognition due to their literary merits and their ability to use the medium of theatre to convey science. These plays have won prestigious prizes, have been translated into different languages, and have been made into major films, attracting much critical as well as public attention to the genre. Science plays such as Hugh Whitemore's *Breaking the Code* (1986),[16] Tony Kushner's *Angles in America*[17] (1993), *Oxygen*,[18] *Proof*,[19] Christopher Hampton's *The Talking Cure*[20] (2002), that according to Shepherd-bar are not 'good' science plays, have greatly contributed to the current popularity of the genre. The widespread commercial and literary success of these plays has raised a greater public awareness of science and therefore has shown how fruitful the conversation between science and theatre can be. Their successful utilization of scientific ideas and their featuring of scientists at their centre have introduced to scientific and non-scientific audience a new forum for the description and representation of science and its practitioners, much more than many other science plays – such as, for instance, Matthew Wells' *Schrodinger's Girlfriend* (2002), *Now Then Again*, or Lauren Gunderson's *Background* (2003), that

[16] A television version of *Breaking the Code* (starring Derek Jacobi) was made in 1996.
[17] Kushner's play has won a Pulitzer Prize for Drama and a Tony Award for Best Play, and a film adaptation of it was made in 2003, which won both the Golden Globe and Emmy for Best Miniseries.
[18] *Oxygen* has been translated into seventeen languages and has been widely published across Europe for educational purposes. The BBC World Service and the West-Deutscher Rundfunk (WDR) also broadcast radio versions of the play in 2001.
[19] Auburn's play won a Pulitzer Prize for Drama and a Tony Award for Best Play, and a film adaptation was made in 2005 staring Gwyneth Paltrow and Anthony Hopkins.
[20] The film adaptation of *The Talking Cure* was made in in 2011 under the title *A Dangerous Method*.

enact science. These plays have given science plays a high profile and therefore should not be excluded from the category of 'good' science plays in a genre they have made a strong contribution to simply because they rely on text rather than performance to convey the ideas that they engage with.

As discussed so far, previous attempts to categorize science plays are to a great extent restrictive. Shepherd-Barr's definition prioritizes theatricality and disregards the fact that some very good examples of science plays rely on text rather than theatricality/performance to convey scientific ideas. Zehelein's definition, on the other hand, ignores the fact that many science plays have engaged both theatricality and textuality, and also that the new direction this genre is taking is towards a devised and cross-disciplinary theatre. Djerassi's overemphasis on the quantity and quality of the scientific content excludes from the genre some of the best examples of science plays such as *The Life of Galileo*, *Hapgood*, and *Arcadia* which have used science metaphorically. Perhaps the time has come to provide a new classification of science plays, which is, at least, less restrictive. However, it is vital to note here that the following classification is based only on modern plays, from the 1990s onwards, and also encompasses only two cultures, British and American.

My close scrutiny of more than sixty science plays (see Appendix 2) has revealed that they can be classified in three categories. The first category, 'Science as Supporting Character', consists of those plays in which science is suppressed to a largely peripheral supporting role and other thematic motifs take the priority. These plays solely focus on the nonscientific issues that science or scientists explicitly raise, such as the life and behavior of scientists, the description of a scientific event, the ethical aspects of the scientific endeavor, and the impact of science on society. In this category, science is *not* used to make a metaphor to explore nonscientific themes and is

superficially imposed. Since the central concern in these plays is not science specifically, they also contain very little in the way of explicit scientific reference. Examples of this category are *An Experiment with an Air Pump*, *W;t*, *Proof*, *Breaking the Code*, and *The Talking Cure*.

The second category, 'Science As the Leading Character', on the other hand, encloses those plays in which science is central as opposed to peripheral. In this category, real science is incorporated at the heart of the play and has become the main subject matter. The plays in this category contain four constitutive elements: a detailed and accurate description/depiction of a scientific idea, a sophisticated metaphorical or symbolic usage of science as a mechanism to explore nonscientific ideas, a science-informed structure, and a strong didactic dimension. These plays tend to display one, some, or all of these elements. In these plays science becomes the leading character whose presence on the stage is necessary because the play cannot exist without it. Examples of this category are *Hapgood*, *Copenhagen*, *Arcadia*, *After Darwin*, and *Oxygen.*

The final category, 'Science as the Director', contains those newer alternative plays that Shepherd-Barr classifies as 'science performance', namely devised or 'made' productions in which cross- and multi-disciplinary approaches are used (216). In this category, theatrical works are not primarily scripted by a playwright; rather, they are created as a result of a close collaboration between designers, performers, and directors. As discussed before, these 'experimental' and 'cutting edge' science performances "have brought science and performance together in inventive and original ways by experimenting with cross-disciplinary approaches, collaborations with scientists, and matching theme to form" (Jordan 14). Examples of this category are Complicite's

Mnemonic and *A Disappearing Number,* Mick Gordon and Paul Broks' *On Ego*, and Fuel Theatre's *Autobiographer* and *Body Pods*.

Regardless of their type and category, most science plays are "attempts to investigate human problems by reference to scientific ideas" (Stokes qtd. in Shepherd-Barr 4). They merge artistic expression with scientific research, and to close the communication gap between the scientific and the artistic cultures. What to Djerassi was once a "rare genre"[21] has proved hugely popular, such that at the turn of twenty-first century it has turned the stage into a site for general speculation about scientific ideas. When Shepherd-Barr (rightly) argued that after the success of *Copenhagen* in 1998 there was an "explosion" of plays and performances with scientific topics (2), Djerassi argued that most of these plays/performances are neither "performed nor published, and the majority of the rest were workshop readings or single minor venue stagings", and are therefore of no significance. He eventually questioned whether there really was an "explosion" in the last few decades or "just a momentary puff?" ("Science on Stage" 97) Shepherd-Barr, however, got it right. The wave of recent science plays in which science is not only being taught but is also being innovatively communicated and integrated into the form of the play or performance has shown that, to use Jordan's words, "the 'event' was far more than 'a momentary puff', and has indeed grown into a genuine artistic/cultural movement" (11).

In *The Unnatural Nature of Science* (1992) Lewis Wolpert says that "Science is arguably the defining feature of our age; it characterizes western civilization. Science has never been more successful nor its impact on our lives greater, yet the ideas of science are alien to most people's thoughts" (6). This is an issue that Djerassi hoped

[21] In his article "Contemporary 'Science-in-theatre': A Rare Genre" published in the special issue on science and theatre in *Interdisciplinary Science Reviews*, (Vol. 27, Number 3, Autumn 2002, pp. 193-201), Djerassi questions Shepherd-Barr's claims regarding the proliferation of science plays in the last three decades.

science-in-theatre could resolve, something that seems not to be happening, at least within the world of theatre. But why is the stage a suitable public space for bringing scientific knowledge to a wider audience? In order to answer this question, we should first examine the intersection between science and theatre.

1.2 From Laboratory to Stage

The closest link between science and literature might be that they both demonstrate our desire to attain knowledge of the world and to solve the mystery of what makes us who we are. As Michael Frayn argues in a 2009 interview with Anthony Gardner for the *Independent*, writers and scientists are united by their mutual endeavor to describe the world in a factual yet imaginative fashion. In a manner similar to writers, he says, scientists are "absolutely marinated in the phenomena they've observed, and out of that comes some huge leap – they suddenly see a completely new framework which explains everything". And just like scientists, Muldoon and Rodgers argue, writers try "to achieve an understanding of the universe of which [they are] a part" (40). It is therefore natural that playwrights, as writers who live in a society in which all aspects of everyday life and social functioning are largely influenced by scientific advances, should turn to science as their source material. Elinor Shaffer explains the general impact of science as follows:

> The interface of science with other disciplines has become a matter of urgency in our time, because science is the dominant intellectual discipline, whose authority, influence and, through its practical application, financial and political power are unequalled. Even on ultimate questions science today has taken the place of both theology and philosophy, and books offering scientific answers to the age-old questions of the formation and end of the universe, the essential character of human nature and consciousness, and the parameters of decision-making about matters of life and death have attained a remarkable popularity. (2-3)

In our techno-scientific world scientific knowledge is suffused with different aspects of our lives: our understanding of the world is often formed by approaches and modes of thinking that rely highly on the tradition of scientific investigation; our culture depends on science and technology for the material means of production; science and technology are vital tools for industrialized societies to achieve power through controlling the environment and legitimizing the forms of domination they exercise; and science has become a central element of capitalist enterprises, enabling them to operate by providing the necessary knowledge for the development of new products and services, and providing wealth for those who control them (Erickson 23). Science has also become an essential component of our free and democratic societies: the work of scientists involves a constant testing of accepted explanations of facts, and interpreting both facts and their explanations in new and original ways. The characteristics of scientific culture are novelty, independent thinking, and dissent, which are all a challenge to established cultural values. Maurizio explains that "The safeguards for independence are free inquiry, free thought, free speech, tolerance and the willingness to arbitrate disputes on the basis of evidence" (221). These values may not be important for science itself but have played an important role in the formation of today's free and democratic societies (221). The maintenance of our modern lifestyles is also contingent on scientific knowledge: we have witnessed a radical growth in life expectancy and medical treatment, a rise in agricultural productivity in line with demographic developments, the ability of technology to free human beings from grueling labor, and unique opportunities and challenges brought about by advanced communication methods, information handling, and computation (221). Scientific discoveries and inventions have changed the way in which we describe the natural world. The transfer of knowledge from a small society of scientific practitioners to an enormous group of

public consumers has led us to understand our world through the lenses of science and to construct our meanings around the scientific worldview. To quote the historian Robert V. Bruce, "Science and technology are the prime instruments of irreversible change in the thought and life of mankind" (3).

Meanwhile, science and technology have become a part of the environment in which literature, as a cultural representation, works. They have become a structuring principle in works whose writers draw images and vocabularies form science and technology for compelling expressions of fresh ideas in their work. In the world of the novel, for example, science acts as an endless source of original ideas. John Dos Passos and Hart Crane both tried to incorporate and to reshape new scientific advances in their respective literary structures.[22] Jack Kerouac and William Burroughs also explored a variety of technologies within their work, as well as making use of technology in their experimental writing techniques.[23] The novelist Ian McEwan, who writes about human nature, literature, and science, argues that what makes science very attractive to novelists with a strong interest in trying new materials is its intrinsic originality. The reason is that human nature is the domain of the novelist and their duty is to endlessly explore it (Shepherd-Barr 49). Apart from that, science has always provided novelists with excellent metaphors; the works of Nabokov, Fowles, Barth, Updike, Vonnegut, Pynchon, and DeLillo are clear examples of this influence. These novelists situate their works not only within a culture which is specifically and wholly influenced by scientific discourse, but also a culture in which scientists play an important role in drawing the attention of novelists to science. In the acknowledgments to her novel *Cat's Eye* (1988) Margaret Atwood writes that "The physics and cosmology sideswiped herein are

[22] For more information see Slade, Joseph W. "Hart Crane and John Dos Passos" in *American Literature and Science*, ed. Robert Scholnick, Kentucky: UP of Kentucky, 2010.
[23] See Lawlor, William. *Beat Culture: Lifestyles, Icons, and Impact*, California: ABC-CLIO, 2005.

indebted to Paul Davies, Carl Sagan, John Gribbin, and Stephen W. Hawking for their entrancing books on these subjects". In *Oryx and Crake* (2003) she thanks the many "non-fiction science writers who provided her with deep background" (435). In his acknowledgment to *The Child in Time* (1987), McEwan says he is indebted to David Bohm's *Wholeness and the Implicate Order* (1980), and has scientists as protagonists of *Enduring Love* (1997) and *Solar* (2010). Janette Turner Hospital mentions three physics books, including Fritjof Capra's *Tao of Physics* (1975), as helpful background material for her novel *Charades* (1988).[24] A comprehensive study of the role of science in novels certainly deserves further analysis, but it lies beyond the scope of this thesis.

Peter Brook, the renowned theatre director, has also found science a fruitful source of novel and illustrative metaphors. He turns to science because "today… we have a new mythology. Science explores the same eternal mysteries with a new symbolic language" (*Threads* 221). Playwrights and theatre practitioners have borrowed images and ideas from science to make metaphors with which to explore human problems. The appeal of these scientific metaphors such as quantum theory, relativity theory, chaos theory, the second law of thermodynamics, and string theory can clearly be identified in most science plays, including those discussed in the following chapters.

In a culture that is highly influenced by science and technology, scientific advances also open up a whole territory of themes and motifs for playwrights and theatre practitioners. The rise in public awareness of science as a social problem after the crisis caused by the development of atomic weapons brought the old motif of the Elsinore/Eden duality of science – the ability of science to bring about both annihilation and progress – to the genre like never before. The bomb that decimated Hiroshima on

[24] See Leane, Elizabeth. *Reading Popular Physics: Disciplinary Skirmishes and Textual Strategies*. Hampshire: Ashgate Publishing Limited, 2007, for an insightful analysis of this trend.

August 6 1945 left ghastly marks on human consciousness and made playwrights and theatre practitioners see science in a new light. This bomb, according to Anne O'Hare McCormick writing in the *New York Times* two days after the event, caused "an explosion in men's minds as shattering as the obliteration of Hiroshima" (22). Describing the bomb as "a profoundly unsettling new cultural factor", Paul Boyer clarified the extent of the situation as follows, "The bomb had transformed not only military strategy and international relations, but the fundamental ground of culture and consciousness" (xix). Einstein also declared in an interview with Michael Amrine in the *New York Times Magazine* on June 23 1946 that "Today, the atomic bomb has altered profoundly the nature of the world as we knew it, and the human race consequently finds itself in a new habitat to which it must adapt its thinking" (383).

After the event, strategists were forced to "think the unthinkable", and writers likewise were compelled to "imagine the unimaginable" (Carpenter 12). Most people sought to interpret the bombs as an apocalypse, the massacre of mankind by man's own hand. Others, conversely, viewed it as a phoenix-like dream of a world in which war was impossible and thus peace was obligatory, as atomic energy brought benefit to mankind rather than detriment.

As a result of the new vision of the world influenced by the existence of atomic power, a polarity between atomic disaster and utopian transformation was generated that left its mark on post-war playwrights and theatre practitioners' science consciousness. They thus began to welcome scientific advancements as sufficient evidence that man was able to achieve perfection and to explain the mysteries of nature, and yet dreaded the thought of having a future where mass destruction of human life was not only possible but also legal and a lived practice. Playwrights and theatre practitioners could no longer see scientists and the natural sciences as existing at the

margins of the society. They instead began to view them as located at its very center, and therefore to ascribe significant meaning to their roles and actions.[25]

In the aftermath of such destructive military conflicts, several nuclear disasters (Three Mile Island (1979) and Chernobyl (1986)) distorted and deflated the public image of science and scientists even more. Ten years later, after the cloning of 'Dolly the sheep', people became even more aware of the Faustian aspect of science; they began to regard scientific progress not as a march toward social improvement, but as a process that was becoming a growing menace to human race. This aspect of science forms the main object of interest for science play practitioners, and leads them to raise questions by employing scientists either as manifestations or embodiments of ideas or scientific issues for the purpose of social commentary. Is science a source of menace or of promise? Is the scientist a hero or a villain? Do scientists have a moral responsibility regarding the deployment of their knowledge? And what kind of scientific research should be allowed, regulated, or encouraged? These questions, along with other questions regarding the future that scientific progress holds and the impact science has on society, cast a dark shadow of anxiety over science play practitioners' perception of the scientific endeavor and its practitioners. As a result, the ethics of science becomes an ever-present character on the stage of a science play practitioner, tapping its foot visibly and strongly.[26]

But regardless of what is felt about scientific breakthroughs and controversies, the place that science has come to occupy in society is extremely important. With a

[25] A discussion of the impact of the atomic bomb on human imagination has already been published by the author in the electronic book *Phoenix Rising from Contemporary Global Society* edited by Lisa Ortiz and Denis O'Hara (2014) under the title of "Scientific Progress: A Hope or an Illusion?: How Post-war Science Playwrights Responded to This Dichotomy".

[26] For more information on the ethical aspects of science plays see Ruddick, Nick. "The Search for a Quantum Ethics: Michael Frayn's *Copenhagen* and Other Recent British Science Plays." *Journal of the Fantastic in the Arts* 11.4 (2001): 415-431; Pasto, David. "The Ethics of the Postmodern Science Play." *The International Journal of Humanities* 9.10 (2012): 111-116.

culture in which science and technology have exercised their fascination, even over those citizens with only the slightest understanding of the actual scientific methods and purposes of the laboratory, people, to use Shelagh Stephenson's words, "now look to science for the answers", instead of religion (qtd. in Taitte 28). This metaphysical as well as factual centrality of science to society has provided playwrights and theatre practitioners with a rich source of ideas. As Allen Lightman argues in "Art that Transfigures Science" (2003), "What science can offer art is that most subtle quality of life, the way that scientists think, the way they live in the world, or what one might call the mind of science. Science and art have different ways of thinking, and those differences, when explored and portrayed, can enlarge both activities".

However, despite the very important role that science plays in our society, public knowledge about science and scientists remains quite limited. Gillian Beer rightly remarks that "The sealed laboratory lies at the center of social fantasy. What goes on there? Do we wish to know? Are we responsible for it? Or is the knowledge generated there the responsibility… of those who produce it?" (321) She then goes on to say that "Such questions have dogged our culture and writing over the past 200 years, presenting themselves often in a positive form for the Victorians, more often as dread in this century" (321). The reason Beer gives for this change is "the mathematization of scientific knowledge. This has speeded up communication between scientists to a startling degree, as if the tower of Babel had been built in a day once the workers found a common discourse" (322). However, this level of specialization has also shut the doors of communication between scientists and the general public. Here, theatre can increase public knowledge about science through translating the complicated mathematical language of scientists into the comprehensible language of the theatre. Frayn argues that scientists are not always the most appropriate mouthpieces for

science, and that they could better communicate the excitement of their enterprise: "I think that it has become fashionable to write up your results in as dull a way as possible" (A. Gardner). Shepherd-Barr believes that this is where "the playwright steps in. By some alchemic magic, the fusion of skilled playwright with 'dull' scientific material brings science to life on stage" (48). She then refers to Alain Prochiantz, the French neurologist who collaborates with the theatre director Jean-Francois Peyret, and who believes that the way the scientists are trained to write up their results is not only "deadening but misleadingly opaque about the hesitation and uncertainties that characterize most scientific endeavor, but get erased in the process of publication" (48).

In "The Search for Quantum Ethics: Michael Frayn's '*Copenhagen*' and other Recent British Science Plays" (2000) Nicholas Ruddick asks the question of why the stage has become the forum for a "serious negotiation" between the sciences and the humanities concerning quantum ethics, and finds the answer in the difference between a play and a movie (133). He argues that the power of theatre lies in its immediacy and live-ness, as opposed to film in which everything represented "has, as it were, already happened" (134). This theatrical characteristic leads to an ongoing interactive and dialogic process between the audience and theatrical artists. The characters are onstage exchanging dialogue with each other while, in a larger sense, the actors are having a nonverbal conversation with the audience. The result of this is that the actors onstage are not the only ones responsible for the effect that a theatrical experience may involve. The audience can, also, to a large or moderate extent, influence the atmosphere, the tone, or the quality of the performance. This can never happen in cinema. In a seminar on *Copenhagen* on 19 November 1999 at the Niels Bohr institute, Frayn explains the interactive dialogue between the audience and the actors with reference to the rehearsals for the play's London premier:

> The actors, even at the end of rehearsals were saying, "Well, I still don't see why he came to Copenhagen." At that point they were also saying, as actors always do, at the end of a long rehearsal period, "Well, I don't think there's anything more we can do in the rehearsal room, we need to get in front of an audience now to find out about what's going on." And I said, "That is why." And I do think that the idea of the human confrontation is absolutely of the essence, the whole of art, the whole of literature, the whole of storytelling, the whole possibility of language and communication. One can't communicate with oneself unless one communicates with others.

This brings to mind the dialogue that, according to Snow, needs to be opened up between the hard and the soft sciences: "Those in the two cultures can't talk to each other" (16). We therefore need a third culture that has "to be on speaking terms with the scientific one" (71). So many science plays have shown how effective this audience-actor interaction can be, suggesting that, as Shepherd-Barr says, the intersection between science and theatre could represent the kind of 'third culture' that Snow envisaged (45).

In addition, due to the very limited resources that audience members are provided with in a theatrical experience, when compared to a cinematic one, they have to use their imagination, which brings a great deal of involvement. The physical limitations of the theatre and the doubly dialogic interaction between the audience and the actors create a deep shared experience between those on and off the stage which, according to Ruddick, is "a measure of unmediated authenticity that is precious in an otherwise highly mediated culture" (134).

In *Drama in the World of Science* (1962) Glynne Wickham explains the contribution made by drama to the investigation of a world in which scientists are in control of everything, from the agricultural and industrial economy to humans' bodily and mental health (47). He argues that, today, the tyranny of science on the human mind, like the earlier tyrannies of "religious bigotry and feudal serfdom" (51), has been so alarming that only drama, as "a forum of the examination and discussion of the human condition, its relationship with its gods, and its interest in itself, collectively and

individually" (52), can protect us from this tyranny. Contrary to what Snow thinks, Wickham argues that the unification of the two cultures is possible through drama due to the extraordinary integrating power of drama, its ability to link the ancient world to the present world, its potential to bring together the edges of critical thinking and creative experiment, and its ability to introduce the artist to scientific thought and the scientist to an understanding of their own human condition (56). Hence, in today's world, where scientific knowledge has broken "what is single and unified in nature" into separate parts and pieces (53), the integrating power of the drama is the only solution to the unification of the two cultures. Now the question that arises is which scientific discipline has provided the richest vein of material for the stage.

1.3 Why Physics?

Physics has always been a powerful source of metaphorical material not only for playwrights and theatre practitioners but also for novelists. Thomas Pynchon, Ian McEwan, John Kessel, and Philip K. Dick are among those who have found inspiration in this field.[27] The same relationship has been going on between theatre and physics. For decades, physics and theatre have enjoyed a high level of interaction with each other, and plays such as Hallie Flanagan Davis's $E=mc^2$ (1948), Friedrich Durrenmatt's *The Physicists* (1961), Robert Wilson and Philip Glass's *Einstein on the Beach* (1976), Ewan MacColl's *Uranium 235* (1986), *Copenhagen*, Stoppard's *Hapgood* (1988) and *Arcadia*, Penny Penniston's *Now Then Again* (2000), *Humble Boy*, Paul Mullin's *Louis Slotin Sonata* (2001), and Nick Payne's *Constellation* (2012) exemplify this interaction.

[27] See Susan Strehle, *Fiction in the Quantum Universe*; Coale, Samuel Chase. *Quirks of the Quantum: Postmodernism and Contemporary American Fiction*, Virginia: U. of Virginia P., 2012; Nashin, J. Paul. *Time Machine: Time Travel in Physics, Metaphysics, and Science Fiction*, Durham: U. of New Hampshire, 1999; Craige, Betty Jean. *Literary Relativity: An Essay on Twentieth-Century Narrative*, New Jersey: Associated UP, 1982.

Shepherd-Barr argues that, "physics plays make up the bulk of science plays" (61). She notes that physics is concerned with subject matter that is by nature dramatic; it involves conflict and controversy, the threat posed by weapons of mass destruction and the possibility of constructing a grand unified theory to unravel 'the secrets of nature'. She also suggests that, within a short period of time, physicists have been able to attract much more attention and publicity compared to members of most other scientific disciplines combined. Playwrights can therefore be quite certain that the audience will recognize the names of Galileo, Newton, Einstein, Heisenberg, Bohr, and other great physicists. Shepherd-Barr continues her argument by asserting that the rapid pace of new discoveries of such magnitude in the realm of physics singles it out from other scientific fields. Due to the recentness of most of these advances, the audience will have a strong "cultural memory" of them, and this, she argues, is one of the main reasons for the proliferation of physics plays in recent years (62).

In "Quantum Theatre – Potential Theatre: A New Paradigm" (1989) David E.R. George reevaluates "all three of the forces which make up the theatre", namely the spectator, space-time, and the actor based on the discursive similarities between theatre and the discussion of physical reality, particularly the quantum nature of reality. What George calls quantum theatre recognizes and enforces a "conception of reality as plural and parallel, indeterminate and hypo-theatrical, the co-creation of spectacular-players", which seems to match and mirror the space-time of "alterability, potentiality, and creative intervention" that he ascribes to quantum physics specifically (174). George argues that quantum mechanics has a wonderful potential to appreciate, speculate and approach theatre:

> The word 'potential'… means 'powerful', 'potent', but as used in quantum theory since Heisenberg, it introduces something standing in the middle between the idea of an event and the actual event, a strange kind of physical reality just in the middle between possibility and reality. The theatre is, of course, just such a

> liminal realm, as is our age as a whole, poised between the possibility of radical change and the actuality of passively attending our own tragedy. (178)

But this potential is not limited to quantum mechanics only. Theatre also has been found to contribute to the discussion of this scientific theory. George argues that the new emerging worldview of quantum theory is theatrical in every respect, and quotes some of the writers in quantum physics who have turned to theatre for the metaphorical explanation of the ways in which the universe appears to them. It will suffice to mention here only a few of them:

> An amusing but hypothetical drama. (Quoting Hugh Everett)
>
> In Einstein's conception, space is no longer the stage on which the drama of physics is performed: it is itself one of the performers. (Quoting Whittaker)
>
> Reality, inasmuch as it has any meaning at all, is not a property of the external world on its own, but is intimately bound up with our perception of the world, our presence as conscious observers. (Quoting Paul Davies).
>
> If the world exists and is not objectively solid and pre-existing before I come on the scene, then what is it? The best answer seems to be that the world is only a potential and not present without me or you to observe it. (Quoting Fred Alan Wolf) (173)

George concludes that these theatrical metaphors used in descriptions of quantum mechanics already point to the forces of theatre which eventually makes this field an appropriate and necessary framework to discuss theatre (173).

Rosemarie Bank also finds the interaction between theatre and new physics useful, appealing, and inspiring:

> We are not physicists fielding theories about the nature of the universe; yet, as one of the most appropriated disciplines in the world – even surgeons, for example, 'perform' in operating 'theatres' – we have long understood the value of analogies that help us and our audiences perceive what we see. It is in the belief that knowledge of the quantum universe has and will continue to enrich performance, play texts, and theatre history in this century and the next. […] Conversely, theatre practitioners and scholars have something essential and unique to say to science about space as we know and use it in our work. (63)

She then suggests that it is unavoidable for theatre researchers to discard Hegelian and Darwinian traditions and adopt the new perception of the spatiotemporal landscape which defines the new relative world that physics, particularly quantum mechanics and relativity theory, have articulated in this century (63).

As George and Bank suggest, one of the main reasons why physics is especially appealing for the study of theatre is the emergence of the revolutionary concepts and theories of 'new physics' or 'modern physics' – developed in the twentieth century from relativity theory and quantum mechanics. The perception of external reality as presented by new physics fundamentally revolutionized the accepted truth of the Newtonian worldview that reality is absolute, deterministic, certain, and fully accessible to the scientist. The standard reality model that new physics envisioned was relative, uncertain, plural, and an indicator of human powerlessness in the face of nature's mystery. The new physics led to, to use Ronald Omnes' words, "the assassination of classical physics" (140), and introduced itself as the only explanation of the behavior of nature and therefore the only accepted model for external reality. Milic Capek explains the "astonishment" generated by the way new physics transformed Newtonian physics as follows:

> There is hardly any similarity between the 'matter' of modern physics and the traditional material substance of the classical period, and this is true in varying degrees of other concepts as well…It is true that the effect of [new physics] on the imagination of physicists, philosophers, and even laymen was truly shattering; the contrast between the new theories and the appealing clarity of classical concepts was sharp and shocking. (xi)

This new physical reality has had revolutionary implications for philosophy, cosmology, theology, politics, economics, and other fields no less than it has inspired a new paradigm in Kuhn's sense of the term. What Kuhn calls a 'paradigm' in *The Structure of Scientific Revolutions* (1970) is a general theoretical scheme or framework that determines all thinking, namely the entire constellation of beliefs, values,

techniques and so on, shared by the members of a given community (175). Thinkers in every field began to explain and clarify this shift, and to write under its influence; it has shaped their perspectives and underwritten the way they see the cosmos around them. The connection between quantum mechanics and eastern mysticism and religion is explored in Fritjof Capra's *The Tao of Physics* (1975) and Gary Zukav's *The Dancing Wu Li Masters* (2001). In *The Physics and Consciousness: Quantum Minds and the Meaning of Life* (2000) Evan Harris Walker explores the impact of quantum theory on neuroscience and psychology. Chris Heunen et al. investigate the relation between grammatical analysis and semantic representations and quantum information theory in *Quantum Physics and Linguistics* (2013). And in *Quantum Politics: Applying Quantum Theory to Political Phenomena* (1999) Theodor Becker explains today's politics with relation to the changed reality proposed by quantum theory. Playwrights and theatre practitioners too, as members of a shared community, are trapped in history and culture and cannot do other than operating on its assumptions. The post-quantum perception of reality has changed their vision of the world and has transformed their thoughts. This is why physics in general and new physics in particular prove influential in areas outside their immediate frame of reference, including theatre.

At the very fundamental level of subatomic particles, Heisenberg asserts, reality is active, dynamic, and actual. To anticipate a discussion that will be completed after an outline of the necessary background in physical science, the main feature of the kind of theatre derived from relativity theory and quantum mechanics is that it is, in fact, a dramatic version of the reality that was introduced by revolutionary theories of new physics in the first half of the twentieth century. This new theatre departs from the unchanging reality of the material world assumed in Newtonian physics and thus abandons and even overturns the conventions of realistic theatre.

1.3.1 Classical Physics

Various historians and philosophers of science have repeatedly told the complex story of the profound change that occurred in the early twentieth century regarding the way physicists viewed reality.[28] A shortened version of this story will show the extent to which relativity theory and quantum mechanics revolutionized previous concepts of reality. However, the revolutionary character of these modern concepts cannot be grasped unless the contrasting background of classical physics is explained in relation to new physics.

In Newtonian physics, all physical phenomena take place in an absolute space, which existed "in its own nature, without regard to anything external, remain[ed] always similar and immovable" (Newton 641). Any change occurring in the physical world could be described with reference to a separate dimension called time, which was also absolute, having no relation to anything external, and flowing equably from the past to the present and from the present to the future. The "absolute, true, and mathematical time" was described by Newton as "of itself and by its own nature, flowing uniformly, without regard to anything external" (9).

In this absolute space and time, material particles, as elements of the Newtonian world, would act on each other through applying forces on each other. Newton regarded these physical particles and the forces between them as created by God. For him, the whole universe has always worked, ever since it was set in motion, like a giant perfect machine governed by immutable laws:

> It seems probable to me that God in the beginning formed matter in solid, massy, hard, impenetrable, movable particles, of such sizes and figures, and with such

[28] See Capek, *Philosophical Impact of Contemporary Physics*; Heisenberg, Werner. *Physics and Philosophy: The Revolution in Modern Science*. Northampton: John Dickens & Co., 1971; and the three volumes of G. Venkataraman, *Quantum Revolution*, Bangalore: Universities P., 1994.

> other properties, and in such proportion to space, as most conduced to the end for which he formed them; and that those primitive particles, being solids, are incomparably harder than any porous bodies compounded of them: even so very hard as never to wear or break in pieces; no ordinary power being able to divide what God himself made one in the first creation. (638)

To put the impact of this force (the force of gravity) into a systematic mathematical form, Newton had to invent a completely new method known today as differential calculus. According to Heisenberg, this new "system of definitions and axioms, which could be written in a set of mathematical equations, was considered as describing an eternal structure of nature, depending neither on a particular space nor on particular time" (85). The concepts in the system were so closely connected that any change in any one of the concepts would destroy the whole system. Capra explains Newtonian mechanics view in a very efficient way:

> The giant cosmic machine was seen as being completely causal and determinate. All that happened had a definite cause and gave rise to a definite effect, and the future of any part of the system could – in principle – be predicted with absolute certainty if its state at any time was known in all details. The philosophical basis of this rigorous determinism was the fundamental division between the 'I' and the world introduced by Descartes. As a consequence of this division, it was believed that the world could be described objectively, i.e. without ever monitoring the human observer, and such an objective description of nature became the ideal of all science. (56)

The impact of Newtonian mechanics on the intellectual life of Europe during the seventeenth and eighteenth centuries was enormous. Capek says that for Immanuel Kant, it was a manifestation of the "unchangeable a priori structure of the human mind" (xiv) and, for Herbert Spencer, the ultimate and definitive result of the long 'process of adjustment' in which the exact replica of the external world in human mind was created in the form of the Newtonian picture of nature. To Spencer and other naturalists of the time, no change was to be expected in this picture. The examples of Kant and Spencer are typical of the belief that the picture of the world presented by classical physics was definitive in its fundamental features, and that if the future were to bring a change, it

would only be a clarification or better perception of its details without changing its basic outlines (xiv). For this reason, the Newtonian model was, for a long time, regarded as final and definitive, and the only task of scientists was to expand Newton's mechanics into broader fields of experience. Physics, in fact, developed along these lines for nearly two centuries.

Almost every social, political, and economic system of the seventeenth, eighteenth, and nineteenth centuries used Newton's revolutionary empirical methodology as a model. In *Quantum Theatre: Science and Contemporary Performance* (2012), Paul mentions some of the thinkers that have been influenced by the Newtonian view of the world: "The extent of this influence can be traced stretching from John Locke, who described himself as a 'mere under labourer' to Newton, to J.S. Mill and then to Adam Smith, Marx, Darwin and Freud. Indeed, Auguste Comte, who first used the word sociology described it as 'social physics'" (24).

And yet, less than a hundred years later, the discovery of a new physical reality made the limitations of Newton's system evident and proved that its features had no absolute validity. The theory of relativity and quantum physics, in fact, shattered all the principal concepts of the Newtonian worldview: that is, "the notion of absolute space and time, the elementary solid particles, the strictly causal nature of physical phenomena, and the ideal of an objective description of nature" (Capra 61-62). This eventually altered the whole situation in physical reality. None of these concepts could be extended to the new domains into which physics was now penetrating.

1.3.2 The Theory of Relativity

At the beginning of new physics stands Albert Einstein. In two papers, one

published in 1905 (“On the Electromagnetics of Moving Bodies”) and one in 1915 (“On the General Theory of Relativity”), he initiated two revolutionary trends of thought: the special and general theories of relativity. The special theory of relativity assumes that light has a constant value, which remains the same in all frames of reference, independent of their motion relative to the light source. It also shows that all measuring values of realistic entities are relative to the frame of reference of the observer, so that measuring equipment would change depending on its motion. A clock moving at high speed, for example on a speeding rocket, runs more slowly relative to a stationary clock on earth. In order for the speed of light to remain the same for both the observer onboard the speeding rocket and the earthbound observer, the speeding observer and the accelerating measuring rod would need to contract to become shorter than the earthbound one. Therefore, from the relative context of one observer’s frame of reference, space (length) appears to contract and time appears to dilate as velocity increases.

In Einstein’s universe, simultaneity also becomes relative to the observer’s frame of reference; those events that happen separately in space might appear as happening ‘at the same time’ to an observer, but either of the two as might appear as previous to the other to another observer, depending on their state of motion. Both observations are valid as there is no absolute frame of reference.

With the discovery of this unexpected link between space and time, Einstein realized that the two can no longer be considered separate and absolute as envisioned in Newtonian physics; rather, space and time are fused together in a four-dimensional structure, the space-time continuum. The rationale behind the space-time continuum is that such relativistic relations would simply not be possible in a three-dimensional world. “As they occur and they are observed”, Weinert explains, “it is legitimate to infer

(a) that the physical world is four-dimensional, and not just a mathematical model, and (b) that this four-dimensional world is static and timeless" (239). In the case of simultaneity, observers moving relative to one another draw different conclusions regarding which events happen simultaneously. All they can agree on is what events there are, not when and where they take place. Space-time, or the totality of all events, is therefore absolute. However, depending on observers' frames of reference there are different ways to slice this totality of events into different frames of simultaneity. When we put these frames together and see them in succession, we realize how, with time, changes happen in space. Looking at different successions of frames, different observers get different perceptions of which events take place simultaneously. Space-time is therefore absolute, but space and time are not.

In his general theory of relativity, Einstein adds gravity to this theory, and describes how gravity curves the space-time continuum and changes its geometry. According to Einstein, unlike Newton's perception of gravitational fields as products of matter applying its pull through empty space, objects warp space-time around them causing it to become curved, and as a result objects experience gravitational attraction to each other. In this curved gravitational field, space, time, and matter do not act as discrete entities; rather they are interacting aspects of the same thing.

Einstein's deepest concern throughout his scientific life was to find a grand unified field theory that could explain all the forces of the universe. The special and general theories of relativity were the results of his attempt to reach this goal by constructing a common framework for electrodynamics and mechanics. He believed in a causal order governing the physical world and a universal science that could explain all levels of reality. Quantum theory, however, took the opposite direction: drawing on Einstein's concept of a world with interrelated phenomena, always observed from a

relative frame of reference, quantum theory took a sledgehammer and pulverized all the marble of its reluctant sire.

1.3.3 Quantum Mechanics

J.C. Polkinghorne describes quantum mechanics as "arguably the greatest cultural achievement of our century" (ix). It is astonishing that a cultural claim can be asserted for an extremely technical, mathematically articulated theory, which is mostly used to describe phenomena at the subatomic level. Quantum theory, first developed as a result of scientists' endeavor to reconcile light with matter, was entirely in conflict with all the science that had come before it. Pre-1900 physics was, in fact, more like a recipe for predicting the future with absolute certainty. Marcus Chown explains the contrast between pre-1900 and post-1900 physics as follows:

> If a planet is in a particular place now, in a day's time it will have moved to another place, which can be predicted with one hundred percent confidence by using Newton's laws of motion and the law of gravity. Contrast this with an atom flying through space. Nothing is knowable with certainty. All we can ever predict is its probable path, its probable final position. (22)

Quantum mechanics was generated from scientists' attempts to explain a phenomenon which had been a riddle for almost a century. They wanted to know why, when hydrogen atoms became excited and emitted light, the emission occurred only at certain wavelengths? When scientists analyzed the spectrum of white light from the sun or a high-intensity incandescent light bulb through a prism, they realized that it consisted of a series of bright colors of green, blue, and red in a 'line emission spectrum'. This continuous spectrum consisted of all possible wavelengths of light in the visible region. Scientists replaced hydrogen with other gases and the same results were obtained. The striking result was that the emission lines of different gases have different

wavelengths. “Knowing the precise wavelengths of the emission lines”, Tsokos explains, “allows the identification of the gas – emission spectra are like fingerprints” (399).

Niels Bohr, the Danish physicist, was the first to provide an explanation for the line emission spectra of atoms. He addressed this problem by postulating that the single electron of a hydrogen atom revolved around its nucleus in a circular orbit. He then assumed that the energy of the electron was related to its orbital radius, but not by using classical physics. According to such laws, the electron could have a wide range of energy. Derived from Max Planck’s theory that the energies were quantized – meaning that they came in discrete chunks that could not be subdivided – Bohr introduced the quantum hypothesis into the atomic model. The Bohr model described the electrons as moving around the nucleus in certain specific orbits, which correspond to specific energies. As John Moore explains, in this model, “the energy of the electron is quantized and the electron is restricted to certain energy levels unless it gains or loses a certain amount of energy” (230). When an atom is heated, its electrons become agitated and leap from one fixed orbit to another. They go directly from one orbit to another seemingly without moving in the space in between: a phenomenon referred to as a ‘quantum leap’ or ‘quantum jump’. The spectral lines are, therefore, emitted as a result of the orbital limitations.

For his theory of atoms that introduced the new discipline of quantum mechanics to physics, Bohr received the Nobel Prize in 1922. The direction of Bohr’s theories, mostly known as the ‘Copenhagen Interpretation’ of quantum mechanics, sharply diverged from the absolute definitive predictions that were the hallmark of classical physics and provided a radically new window from which to understand the world. The experiment that best gives a detailed understanding of quantum mechanics is the

'Double Slit Experiment', which the physicist Richard Feynman describes as containing all the mysteries of quantum mechanics to such an extent that "any other situation in quantum mechanics, it turns out can always be described by saying 'you remember the case of the experiment with the two holes? It is the same thing'" (130).

1.3.3.1 The Double Slit Experiment

A particle has a definite position, and acts as an individual thing. A wave, on the other hand, is a periodic pattern, with no definite position. It can at times interact with other waves constructively and at other times interact destructively. When something behaves as a wave and a particle at the same time, the wave-particle duality is formed. Photons and electrons are an example of this. Classical physics is completely unable to explain this phenomenon, and this is the domain where quantum mechanics kicks in. The double-slit experiment helps us understand how wave and particle properties might coexist in subatomic particles.

In this experiment, we fire electrons through a screen with two slits in it. Behind the screen, there is another screen that shows the position of the electrons that have passed through the slits. Strikingly, the manner in which the electrons strike this screen is entirely different from the manner that is expected of their nature as particles and of the two-slit apparatus. Although they arrive individually at a discrete point on the screen, collectively they in fact spread out and produce an interference pattern similar to the one formed by waves of water when passing through a two-slit box placed underwater. Peter Hodgson describes the dilemma as follows:

> The problem of the double slit is that neither the wave nor the particle picture seems at first to be satisfactory; if the electrons are waves, then why are they detected like particles, each at a particular point on the screen, whereas if they are particles, then they must go through one slit or the other, and then how does the

interference pattern arise? (141)

It might be assumed that the reason why the interference pattern is formed is because of the diffraction between electrons passing through the two slits. But even if the electrons are shot through one at a time, the interference pattern remains. It is posited that what is passing through the slits is a probability wave, meaning that its location is not definite; rather, it has a probability of being in any particular location. Electrons therefore have both particle-like and wave-like characteristics. This phenomenon, which is referred to as Bohr's Complementarity Principle, shows that in order to understand the subatomic world, we need both the two contradictory yet essential properties of the electron: wave and particle.

In another variation of this experiment, the electron detectors are placed right at each slit in order to detect and count the single electrons as they pass through the slits. This helps to resolve the ambiguity over which slit an individual electron passes through. By performing the experiment this way, we are able to count individual electrons by each detector and therefore identify them with passing through either one slit or the other, not both. Nevertheless, in doing so, no two-slit interference pattern will be obtained. This means that, as Shelton explains, "Observation (measurement) collapses the wave function, causing energy's wave-like aspects to localize in particle form" (15). Adding the electron detectors to the apparatus actually changes the observed outcome. The single electron, therefore, seems to leave as a particle, become a wave of potentials, go through both slits and interfere *with itself* to get to the detector screen as a particle.

The experiment shows that, on the quantum level, the outcome may be considerably affected by the interaction between the experimenter and the experiment. Scientists or their equipment are no longer passive observers of nature; rather, they must

be thought of as active participants in a physical process. This is referred to as the Observer Effect.

The wave-like behavior of particles in this experiment causes another quantum phenomenon, known as Heisenberg's Uncertainty Principle, which reinforces the observer effect. According to Newton's second law, the velocity and position of an electron can be measured simultaneously (and with arbitrary accuracy) if the initial conditions, velocity, and all the forces acting on the particle are known. However, in the quantum world, it is impossible to measure simultaneously the position and the momentum of a particle to an arbitrary accuracy. We saw that in the double-slit experiment particles emit through the apparatus as a superposition of waves, yet when measured land on the screen as particles. Since wavelength is related to momentum, it is only possible to either "measure the location with arbitrary accuracy but lose any ability to measure momentum [or] to allow the interference pattern to build up and get a very accurate value for the momentum of the particles but lose any ability to calculate positions of the particles while radiating through the apparatus" (Quill 12). The choice is made by the experimenter.

1.3.3.2 Quantum Entanglement

According to the Copenhagen Interpretation of quantum mechanics, interacting elementary particles become entangled and their interconnectedness is because they effectively share the same probability wave. These particles remain entangled until an observation is made. "When one entangled particle is measured for a particular characteristic, say position, the shared probability wave collapses, and all the entangled particles simultaneously collapse into reality with definitive positions" (Zarem 82). This

aspect of the quantum world is termed non-locality and runs counter to classical physics, according to which an object is only directly influenced by its immediate surroundings (principle of locality). The entanglement of particles demonstrates that there are immediate interactions, connections, and interdependencies across vast reaches of space. This is what Einstein famously referred to as 'spooky action at a distance'.

This is in direct contravention with what Einstein has already established about the speed of light: the fact that it is the maximum speed with which anything in the universe may move. According to non-locality, instantaneous action or information transfer is possible. The impossibility of distant objects having a direct influence on each other, and the idea that objects are only affected by their immediate surroundings, appear to have simply lost validity.

1.4 Implications of the New Physics

Ever since Einstein's publication of his four-dimensional depiction of space-time, the governing view in physics and philosophy has been that time is a fourth dimension, such that it has blurred the sharp distinction between past, present, and future. Relativity physics, with its emphasis on the observer, has transported the moving present from the superstructure of the universe to the minds of human beings. In any discussion of physical time, the forward flow of time and the consideration of 'now' must inevitably be abandoned due to these concepts being meaningless within the domain of space-time. 'Time in the clock', to put it simply, has gone out of the window. This temporal relativistic perception creates a world known as a block universe, in which "the whole histories in time of all physical objects are given as completed four-dimensional entities… since all moments of time are not 'getting actualized' one by one

to become the moment ‘now’, but form the fourth dimension of the world and hence are all given at once” (Petkov 122). As a result of this discovery, it is revealed that not only does time not flow, but also that the difference between past, present, and future is only an illusion. Consequently, the belief that only things that currently exist at the present moment are real should be abandoned, and instead the claim that all past things and future things are real, even though they do not exist now, should be accepted. The contrast between the openness of the future and the fixity of the past should be abandoned too. In Einstein’s universe, space (length) contraction also invalidates the idea of distance between ‘here’ and ‘there’, and shows that the distinction between them is merely an illusion.

Quantum measurements, on the other hand, introduce an inevitable element of duality into the nature of reality. The wave-particle conundrum, the central dualism at the heart of quantum theory, shows us that at the most basic level of the universe, the nature of things, subatomic entities, is necessarily double. They exist both as waves and particles, two incompatible yet necessary concepts, neither of which can be observed at the same time and each of which is mutually exclusive in terms of how we observe them. The complementarity principle therefore shows that mutually exclusive states of existence define the very nature of the universe, at the heart of which lies a great deal of contradiction and paradox. As Heisenberg puts it, “We are reduced to using parables, that is to say, complementary interpretations that contain paradoxes and apparent contradiction” (qtd. in Pullman 360). Reality was simply no longer black and white. Its true Janus face was finally revealed.

In a series of speeches in Copenhagen in the late 1920s Bohr acknowledges that “Subatomic entities such as electrons have no real existence; they exist in a probabilistic limbo of possible superimposed states until forced into a single state by the act of

observation. The electrons or photons may act like waves or like particles, depending on how they are experimentally observed" (qtd. in Moar 63). The role of the observer in determining the nature of reality, along with the uncertainty principle, indicates that it is the scientists' subjective interaction that gives reality to the position and momentum of the particle and to the particle itself.

Scientists' decision to select which aspect of nature to describe opens a window towards a wide spectrum of possibilities. In the new physical reality, Heisenberg says, "science no longer confronts nature as an objective observer, but sees itself as an actor in this interplay between man and nature" (qtd. in Strehle 13). And according to Strehle this is the very place where physics meets philosophy, as when the scientist, "for centuries a figure typifying neutrality, distance, and passive observation, becomes an actor in the interplay, the entire set of relations between mind and world has changed" (13). This added element of subjectivity to the act of observation makes scientists' attempt to explicitly determine what is there before an observation, between observations, or after observations always fail, due to its contradiction with the experimental data. In other words, talking or even thinking about what is out there prior to an observation is meaningless; reality is formed the instant the observation takes place, the moment when a definite material description can be made from the observation. In the quantum realm, therefore, reality can be seen by us at particular moments which are, in fact, constructed and limited by our observations, by our measurements: they form and shape our perception of reality. As Niels Bohr explains, "There is no quantum world. There is only an abstract quantum description" (qtd. in Bub 11). This indicates that there is no absolute reality, no definite certain description of nature independent of our observation. Reality as we know it is a subjective construct and therefore can only be quantified as a set of probabilities.

Quantum discontinuity also adds another level of probability to this limited understanding. An electron's transition between quantum states through time from here-now to there-then without ever appearing at any place in between shows us that there is no linearity or continuity at the heart of the most basic elements of the universe. "This discontinuity", Amit Goswami explains, "means a breakage of causal continuity; we cannot give a precise cause as to when an electron is going to make a jump. Or if there is more than one orbit of energy level to jump to […] we cannot say precisely which orbit the electron is going to leap to or when" (40). This means, in other words, that at the heart of all that is, jumping matter and unpredictable motion are random and discontinuous.

Moreover, in the absence of locality assumptions, the universe becomes a place where things are potentially intimately connected regardless of how distanced or unrelated they might be. As Fraser and Massaey explain, "The world is a vast web of relationships, with everything affecting everything else. Every particle is correlated with or may even casually affect every other particle across the expansive fabric of space-time" (51). As a result, the local chains of cause and effect that we can observe for phenomena immediately interact with distant phenomena, in ways that are far from our causal perception of universal connections.

In the new physical reality presented by quantum theory, the most basic entities and events are irreducibly discontinuous and paradoxical, and knowledge of them is probabilistic, subjective, and uncertain. This theory presents an extremely fluid perception of our world and ourselves; one in which ultimate grounding is meaningless. Flux replaces foundation in such a way that we are left with the notion that reality is ultimately relative, discontinuous, paradoxical, subjective, indeterminate, and nonlocal. Maybe it is time we changed our perception of the world and began to view things in the

light of quantum reality.

1.5 Physics and Theatre Reimagined

Erich Auerbach argues in *Mimesis: The Representation of Reality in Western Thought* (1953) that the matter and manner in which artists represent their work are extremely influenced by the definition of reality formulated by cultural beliefs. A changed view of reality thus disproves the former conventions through which theatre refers outward and necessitates the invention of new ones. The new physics can clarify and define this new framework within which a new theatrical mode can be analyzed, a mode which is largely different from its predecessors.

The Newtonian physics formulated in the seventeenth century had a profound impact on realistic drama and provided the ideological paradigm for it. In *Naturalism in the Theatre* (1881), Emile Zola discusses the impossibility of separating dramatic art from the nineteenth-century scientific revolutions and describes the desire to direct theatre towards the representation of reality as allowed within the paradigm of Newtonian physics (365). Martin Esslin also explains that the 'good play' was defined by "a cleverly constructed story… subtlety of characterization and motivation… [and its ability] to hold a mirror up to nature" (3). The nature reflected in the 'good play' was, therefore, of a "well-ordered, linear, continuous" nature (Johnson 2), which lent itself to being perfectly analyzed within the Newtonian paradigm. As Hugh Skyes Davies asserts in *Realism in Drama* (1934), Realism introduced to the theatre the method of "[Newtonian] science, detached observation, suppression of the opinion of the observer, and a faithful report of the plain truth" (93). The imaginative activity in realistic theatre was modeled based on one of the essential principles of Newtonian physics, namely

scientists' objective observation of nature. Realistic playwrights and theatre practitioners could confidently represent the objectively real in theatre, because they assumed, as Newtonian scientists did, that they knew its essential structure. Since in the dominant scientific paradigm of the time, there was an absolute objective space within which reality existed, external to consciousness, the playwright/theatre practitioner, similar to the scientist, employed an impersonal gaze and observed characters and things within the context of linear causal time, to eventually draw lucid, predictable, comprehensible, and final results. Their task as writers was simply to hold a mirror up to nature or to take a sample from society and present 'a slice of life'. The reality they produced was eternal, reflecting the static frame of reference that Newton posited as validating earthly experiments. Nothing was left to chance, left unassimilated, or left uncertain.

Parallel to the gradual loss of the dominance of Newtonian physics in the realm of physics, the dominance of realism in the world of theatre was also challenged. The new physical reality suggested by relativity and quantum theories showed the playwrights and theatre practitioners that reality per se is not realistic; rather, it is relative, discontinuous, accidental, and uncertain. The quantum reconceptualization of reality, "from ordinary sense perception to something far harder to picture" (Johnson 35), necessitated the need for a new theatre to which playwrights and theatre practitioners responded. Among twentieth and twenty-first century theatrical genres, the science play often departs radically from the expected realistic reality. It not only displaces Newton's absolute domain with the model theorized by Einstein, Heisenberg, and Bohr, but also reconceives theatre's relation to actuality. In this new model, theatre can no longer be the transparent glass or reflective mirror that only represents the external reality observed by the naked eye; rather, it responds to an understanding of an actual subatomic reality as profoundly changed. Science playwrights and theatre

practitioners reject Newtonian absolute frames of reference, causality, continuity, objectivity and certainty, and instead opt for a juggling/overlapping of temporal and spatial frames, a nonlinear and non-causal plot development, a multidimensional web of plural realities, and an uncertain solution or answer.

However, science plays can be viewed as realistic in the sense that they are often written with reference to real science and real-life people and events. They take history and science, mix them together, and make accurate scientific and biographical references while translating, to use Shepherd-Barr's words, "'real-life' material into a fictional world" (194). This ability to combine realistic-looking/sounding characters and real science with non-realistic elements is one of the unique characteristics of many contemporary science plays. The genre does not abandon reality, but questions it by making the task of science play practitioner, as Wertenbaker explains, "very simple, to ask questions… All a playwright can do is capture and phrase the questions as immediately as possible" (qtd. in Shepherd-Barr 42).

Thanks to the changed reality posited by the new physics, contemporary science practitioners do not confront the same external conditions as their realistic successors: they write and perform in relation to a changed external world. Their works are formed and defined within the context of the events and ideas happening in larger fields of discourse. Evolving from interconnected thinking about reality in physics and in fiction, science plays establish a theatre open to the dynamic and multiple relations that define the quantum universe. The following chapter sets out the framework within which the contemporary science plays can be discussed and explored from the standpoint of new physics.

Chapter 2

New Physics and Contemporary Science Plays

In the curved space-time universe of relativity and the subatomic realm of quantum mechanics, contemporary science plays create and express a kind of theatre that captures the increasingly widespread perception of reality as relative, inconsistent, contradictory, subjective, indeterminate, and local. They reinvent authorship: no longer an essential deity, science play practitioners climb the tower of Truth and float through an irregular, indeterminate universe in which the only position they are allowed to choose is that of uncertainty. They authorize both/and thinking rather than either/or and form a new model of theatrical complementarity where contradictory voices, perspectives, and possibilities unite as one. They abolish Newtonian absolute time and space and opt for a flexible relative perspective, which allows discontinuity and nonlinearity to break up the natural flow of events into discrete chunks. They create a universe in which distanced realms instantly become entangled and create a unified system of connections.

In this chapter, twenty-four emblematic science plays are discussed within the context of post-quantum reality in order to set out the parameters that the new physics paradigm supplies. This chapter provides the necessary tools for a thorough and detailed analysis of the six specific examples that will structure this study's argument concerning new physics and contemporary science plays in the subsequent chapters. This chapter also discusses the thematization and the functionality of science in these twenty-four science plays.

2.1 Time-less Time and Space-less Space

In his essay "The Work of Art in the Age of Mechanical Production", Walter Benjamin comments that "A clock that is working will always be a disturbance on stage. There it cannot be permitted its function of measuring time… Astronomical time would clash with theatrical time" (247). Einstein's experiments in time and the removal of its certainty as an absolute uniform category made the conventional temporal experience unnecessary to the theatrical experience. Along with the deregulation of time, fictional qualities also shadowed the factuality of space; rather than forming lucid relationships between solid characters and a solid world, science play practitioners began to displace characters and the audience, as space was no longer considered detached from time but part of the same energized field. Freed from the unified psychological time and space that had characterized theatre, science play practitioners found new reasons to slow down, to speed up, restrict, and dilate the flow of theatrical time and the transportation of space. Within the frame of the stage, the play could illustrate historical time/space, future time/space, and time/space outside of time/space. In the territory of the theatre, time/space had the option of going backwards, racing ahead, jumping around in a disorderly fashion, or turning into a character with its own energy. Science play practitioners began to regard all points in time and space as being simply 'there', existing even if not experienced yet or already experienced. In other words, all of time (past, present, and future) and all of space (here and there) were seen as constantly in existence; they did not 'flow' or 'transport', they just 'were'. In contemporary science plays, the past, present, and future, and here and there, are collapsed into a static continuum; a time-less 'now' and a space-less 'here' that has entered the perception of theatrical reality.

Arcadia, *Copenhagen*, *Remembering Miss Meitner*, Ira Hauptman's *Partition* (2003), Erin Lavik's *Galileo Walking among the Stars* (2004), Carey Perloff's

Luminescence Dating (2007), and Lauren Gunderson's *Emilie: La Marquise Du Chatelet Defends Her Life Tonight* (2010) all take us beyond the limits of time and space by depicting certain historical worlds in direct communication with each other. These plays displace the conventional map of theatrical space/time by jumping from one historical world to another, or by having them simultaneously present on stage.

In *Arcadia*, chaos theory[29] is metaphorically used to show that minor decisions in life may lead to major consequences. For example, a tutor's, Septimus Hodge's, decision not to accompany her genius mathematician student, Thomasina Coverly, up to her room leads to the latter's tragic death in a fire caused by a candle in her room. Thomasina's death also causes Fermat's last theorem[30] to remain unsolved and therefore Septimus to shut himself up as a hermit fruitlessly trying to solve Thomasina's last theorem. The stage space in *Arcadia* is confined to a single place, a sitting room in an English country house named Sidley Park. However, Stoppard presents the passing of time as a cyclical continuity in which the past keeps having its time again. The play shuttles back and forth between 1809 and 1993 where, in the present day, two American literary critics attempt to piece together the events that took place at Sidley Park in 1809. In the historical scenes, the characters that are being investigated appear onstage and enact the past that is being referred to in the current era. In the play, the past and the present are always featured separately until the final scene, in which the natural flow of time is interrupted by constant temporal leaps from one period to another. This presentation of the passing of time as nonlinear and discontinuous reaches its climax when the characters from the two time periods share the same stage in a costume ball.

[29] Chaos theory indicates that the behavior of complex systems is highly sensitive to small changes in their initial conditions, for example a butterfly flapping its wings in one part of the world can change the weather pattern in such a way that it causes a hurricane in another.

[30] According to Fermat's Last Theorem no three positive integers a, b, and c satisfy the equation $a^n + b^n = c^n$ for any integer value of n greater than two. It has been believed since antiquity that $n = 1$ and $n = 2$ have infinitely many solutions. The proof of Fermat's theorem was completed in 1993 by Andrew Wiles, a British mathematician working at Princeton in the USA.

The large table at the center of the stage, which accumulates props from the two time periods, is a place where the past and present intersect.

The idea of certain historical worlds being in direct communication with each other is also a location of fruitful work and thought about time and space for Ira Hauptman. *Partition* focuses on the collaboration between two early twentieth-century mathematicians, Srinivasa Ramanujan and G.H. Hardy, and the conjecture of the seventeenth-century French mathematician Pierre de Fermat. In the play, the present-day characters' attempt to prove Fermat's last theorem with the help of the goddess Namagiri, the personal deity of Ramanujan, is what connects the past and present together. *Partition*'s space-time constantly moves around, taking giant leaps from the past to the present and from here (England) to there (France) to connect the two time frames together. Similar to *Arcadia*, the two time periods are presented separately, divided by fades and blackouts. As the play progresses, however, the times begin to merge through the echo of Fermat's malicious laughter in the present. At different occasions in the play also, characters from different historical periods share the stage together.

Rather than using the constant time travel of Stoppard and Hauptman between different historical worlds, Lavik, Perloff, Frayn, Friedman, and Gunderson have their historical characters travel all the way from their time/space zone to appear in a present-day setting. These characters enter the relativity chamber and are mysteriously teleported to another realm with different temporo-spatial characteristics. This simply is not possible in the world we thought we knew.

Lavik's *Galileo Walking Among the Stars*, a play by an associate professor of biometrical engineering and a professional wedding cake baker, features Raphael, a lonely scientist confined to a hospital bed with her life nearing its final chapter. Through

her imagination/hallucination, three famous dead scientists, Galileo, Johannes Kepler, and Thomas Harriot, travel from sixteenth-century Italy, Germany, and Britain to a present-day hospital room in Chicago to build a spaceship to explore the heavens. Throughout the play, we have the constant simultaneous presence of the past and present characters on stage interacting with each other. The famous American dancer, Gene Kelly, also occasionally appears on stage to dance with Raphael. Lavik's play contains passing information about the scientific discoveries of its characters and reveals to the audience the competitive nature of scientists.

In *Luminescence Dating*, Perloff makes the stage a meeting-point of the past and present by summoning a mythological character, Aphrodite, from the past to a present-day setting. Angela Hart, a successful American archaeologist, is exhausted that her fifteen years of constant research to find the great statue of Aphrodite, an object of intense worship that disappeared in the fourth century BC, have been completely fruitless. Parallel to this archeology-based story are two love stories, between Angela and her colleague Nigel Edwards, and a male-to-male love story between a queer theorist, Victor Reid, and a young scholar who only has eyes for Nigel. Perloff's weaving together of the archaeologists' attempts to dig into the history of the Aphrodite statue and their romantic entanglements summons the goddess of love to spatially and temporally travel from fourth-century Cyprus to a present-day archaeology lab in America. She appears in the disguise of an old cleaning lady and begins to interact with the archaeologists to right the ship and bring both their romantic and professional lives to a successful conclusion.

In their plays *Copenhagen*, *Remembering Miss Meitner*, and *Emilie,* Stoppard, Friedman, and Gunderson magically transport their scientist characters back from the dead to a present-day stage to examine the questions that they left unanswered. The

founding fathers of the Copenhagen Interpretation of quantum theory attempt to answer the question of why Heisenberg paid Bohr a visit in Nazi-occupied Copenhagen in 1941. Meitner, the co-discoverer (with Otto Hahn) of fission, wants to know why Hahn, after receiving the Nobel Prize for Chemistry in 1944, did not give her credit for her role in helping to discover nuclear fission. And Emilie wants to answer the question she died with: love or philosophy, head or heart?

In *Copenhagen*, one female and two male characters populate the stage and discuss their actions, motives, and words for answers. Bohr, his wife Margrethe, and Heisenberg travel back in time, through their memories, yet forward in space, to a present-day stage in 1998, to understand what happened during the 'Copenhagen encounter'. However, as their memories constantly fail them, they are repeatedly led back to 1941 to examine and re-examine the meeting to eventually give the audience an authentic account of events. This process of editing and revising causes the characters' backward-looking reflections on the event to deliver only a series of half-imagined, half-remembered 'drafts' that spiral out into a galaxy of intellectual mysteries, complexities, and uncertainties. In the course of the characters' investigations into the past, Frayn explores the ethical conflicts facing scientists with regards to the use of the potentially fatal scientific discoveries.

In *Remembering Miss Meitner*, the same backward-in-time-forward-in-space motion is employed. Forty years after Meitner's death in 1968, she, Hahn, and the Swedish physicist Manne Siegbahn are brought in direct contact with a twenty-first-century audience to tell a story of physics and betrayal. Each character remembers the events differently and therefore presents his/her own version of what happened. Meitner accuses her colleagues of betrayal and they attempt instead to prove that they gave her the credit she actually deserved. They therefore directly address the audience and leave

it to choose which it prefers. However, unlike Frayn, Friedman seems to be in favor of resolving the mystery of the play and gives the audience enough clues to return home after the performance thinking, "What happens when you do what you're supposed to? You do it damn well and you're denied credit for what you deserve?" ("Meitner Might Right") He seems to suggest that in the realm of science, ethical issues are sacrificed for the sake of fame and recognition. Similar to *Arcadia*, Friedman places a table on stage, which is home to past and present scientific articles and journals, primary and secondary sources, and old and new material. This table allows the two time periods to coexist on stage before the eyes of the audience.

In order to answer her question, Emilie summons the men in her life (her husband, her lover and scientist partner, Voltaire, and a soldier-poet who later becomes her lover) from seventeenth-century France to a stage in America in 2010 to begin her reverse journey into the past through the act of remembrance. The audience therefore witnesses different temporal and spatial points in Emilie's life rapidly unfolding on stage and immediately connecting with each other to keep up with the pace and the order of the flashbacks that Emilie wants to be performed. She announces each scene, like a chapter in her life, and this is followed by the actors recreating them. Similar to Meitner, Emilie also directly addresses the audience, underscoring the simultaneity of past and present, of here and there. This collision of the energy fields of (dead) real historical characters and the (alive) audience makes the normalized experience of time and space less essential to the contemporary theatregoer.

Rather than having certain historical worlds in direct communication with each other, *Now, Then, Again*, Arthur Giron's *Moving Bodies* (2000), Chiori Miyagawa and James Lattis's *Comet Hunter* (2003), Lauren Gunderson's *Background*, Paul D'Andrea and Jon Klein's *The Einstein Project* (2004), Bob Clyman's *Secret Order* (2009),

Deborah Stein's *Bone Portraits* (2009), *Constellation*, and Lucy Prebble's *The Effect* (2012) prefer to connect different temporal and spatial units within a specific time frame.

In *Moving Bodies* and *Secret Order*, the former a dramatization of the biography of Richard Feynman and the latter the story of William Shumway, a young idealistic biologist with a brilliant new idea for curing cancer, the temporal and spatial leaps happen freely on stage from one point to another within the framework of the lives of the protagonists. In *Moving Bodies* the audience witnesses different stages in Feynman's life, from childhood to adulthood, unfold on stage in a nonlinear fashion, and along with it travels to different places all across America and Mexico. The play shows the teenage Feynman at the Chicago World's fair in 1933 before suddenly jumping to 1935, where he and his sister are outside their parents' house in New York investigating the sky. It then takes the audience to a Challenger Mission session in 1986 in Florida, and from there to a hospital in Mexico where Feynman's wife, Arlene, is sick in bed. In *Secret Order*, different moments in William's life following his decision to collaborate with the Hill-Matheson Institute, until his dismissal due to power plays and strategic deceptions, are enacted on stage. The play's spatial and temporal travels happen so rapidly that it seems as if all the characters are on stage waiting for the lights to go up on them so they can take the audience members to different points in time and space; in the blink of an eye, the audience is taken from a lecture room at the University of Illinois to a hotel room in London and then to a prestigious lab in Manhattan. The nonlinearity of time and space is underlined in the play by having the present instantly turned into the future when the characters on the phone suddenly appear on stage, continuing the conversation in person. Similar to Lavik and Friedman's plays, *Secret Order* is a clear depiction of the competitive nature of scientists and the fact that what motivates their endeavor is in

fact fame and money rather than sheer pursuit of knowledge.

Another science play that seems to have discarded the realistic clock is *The Effect*. The play grapples with the ethics and practice of scientific research by featuring two young volunteers, Tristan and Connie, who have agreed to take part in trials of an experimental antidepressant called RLU3 with adverse side effects in exchange for money. Their behavior is being tracked by a psychiatrist, Dr. Lorna James. Over the course of the play, the protagonists start to fall in love with each other, wondering whether it is instinctive or simply a result of being given large doses of dopamine. We follow the story of this attraction/love through the one-month course of the trial, and afterwards in a hospital room where Tristan is seeking medical help for the fatal side effects of the drug. The moments of Tristan and Connie's relationship throughout this period are often enacted on stage like a sequence of very short-run frames, not more than a beat, constantly interrupted by blackouts and lights-up. At different points in the play, Tristan and Connie are in separate spaces at two different points in time, being interrogated by Dr. James about their psychological and physical states after drug-taking. However, despite their temporal and spatial distance, the dialogue is arranged in such a way that Tristan and Connie's lines are constantly interspersed with each other, suggesting that they are both in the same place at the same time being simultaneously interrogated. This causes a travelling in time and space that can happen instantly on stage with no interruptions, so that the idea of a single time frame seems intact.

Bone Portraits is a science play that follows the same line of time/space perception. Stein explores the unexpectedly dark consequences of scientific discovery by focusing on America's obsession with the invention of the x-ray machine in the late nineteenth century. After the discovery of x-ray by Wilhelm Roentgen in 1895, hand x-ray images became quite fashionable among women. The extremely dangerous effects

of x-ray radiation, especially to those operating the cameras, were quite unknown to scientists at the time. Clarence Dally, an assistant to Thomas Edison in his work on x-rays, was one of the early victims. *Bone Portraits* alternates between the stories of Roentgen and of two Americans, Edison and Dally, who exploited his invention. Another character who figures peripherally in the show is the scientist Pierre Curie who, like Dally, died of radiation poisoning. The time/space structure in Stein's play follows an undisciplined nonlinear pattern so that it is often difficult to keep the track of the different stories and characters. In a series of disconnected sketches, audience members are taken to different temporal points in the 1890s where they can witness the invention of the x-ray machine, its popularization in America by Edison, the public reaction to it, and different points in the lives of the people either involved in its invention or suffering from its consequences. This nonlinearity is further highlighted when different characters from different points in the 1890s share the stage. Audience members' conventional understanding of space is challenged by taking them to different places across the globe either simultaneously or asynchronously; from the World's Fair Exposition in Chicago in 1892, they are taken to Roentgen's house in Germany where his wife, Berta, is sick in bed due to radiation poisoning; from there they travel to different festivals and drawing rooms across America; then they go to France to see Marie Curie desperately trying to contact her late husband's spirit with the help of a medium; and they finally land in Edison's laboratory in Menlo Park. Audience members can also be in two different places across the globe at the same time; they watch Berta sleeping in bed in Germany, and Josephine, Clarence's wife, sleeping in a chair in America. These temporal and spatial fluctuations are employed in the play with no blackouts or interruptions.

Similar to *Copenhagen*, *The Einstein Project* uses constant temporal and spatial travel to portray the ethical issues that potentially lethal scientific developments raise.

The play opens in 1919 when Einstein's theory of relativity is proved, and then jumps forwards in time to Japan where the atomic bomb Einstein urged Roosevelt to build is detonated, and then goes back in time to the patent office in Switzerland where he works as a clerk, and then forward again to a hot discussion in Berlin between him and Fritz Haber, the inventor of mustard gas, and then even further to the World War II era, to contextualize the decision Einstein made, as a pacifist, to cooperate with the U.S. Government, a decision that resulted in the bombardment of Hiroshima and Nagasaki. The episodes enacting different stages in Einstein's life are constantly interrupted by those in which his fellow physicists, Hahn, Heisenberg, Max Von Laue, and Walter Gerlach, in different places, across Germany and England, and different time units, from 1920 to 1945, discuss their decision to stay in their homelands and resist such weapons research. The last stop of this train of non-chronologically ordered episodes is somewhere outside of time, maybe in an afterlife or Einstein's dream, where a Japanese woman prepares a tea service with great elegance.

In *Now, Then, Again* and *Constellation*, playing with time and space turns into a complex web of backward and forward motions. Penniston and Payne write about love but develop it through the concepts of quantum theory. *Now, Then, Again* uses the transactional interpretation of quantum mechanics which describes a quantum interaction in terms of retarded waves (forward-in-time) and advanced waves (backward-in-time) to show the degree our lives are affected by our personal choices. The play deals with the amorous adventures of two young genius physicists: Ginny, a talented undergraduate physics student, and Henry, a gifted but socially challenged scientist. The first act moves forward in time: now, now plus one day, now plus two weeks…, featuring Henry terrified of making a presentation due to his paralyzing fear of public speaking, Ginny marrying her childhood sweetheart and giving up her pursuit

of science although she has won a prestigious award in physics, and Felix, a clairvoyant janitor who is determined to make a match between Ginny and Henry, dying of a brain tumor at the end of the act. In Act Two, however, the process is reversed: now plus thirteen weeks, now plus ten weeks, going backwards in time. We see Felix living again, having a new observation, decision, choice revealed to us at each step, until we reach the beginning, the 'now', which is different from the 'now' in Act One. Penniston initiates a new future at the end, a future for Ginny to be with the bumbling but cute Henry who will encourage her research, personal career, and life satisfaction. The audience, therefore, "experiences the hour that moves the story backwards in time as forward in the play and in their evening out" (Fischer 253). Due to the play's reversal of time, the audience is also immediately transported back and forth between different places, such as a laboratory in Batavia, Henry's office, Gene's office, an airport, and a hallway with a burnt-out light bulb.

In *Constellation*, on the other hand, the time reversal is used to enact the many-world interpretation of quantum theory, according to which we are a part of a world with an infinite number of universes where several different outcomes and possibilities exist simultaneously. Roland, an easy-going beekeeper meets at a barbecue the intelligent, witty Marianne, an astrophysicist at the University of Sussex. Payne shows the couple, after the meeting at the barbecue, either experiencing different rituals of betrayal, co-habitation, and separation, or going their own ways, running into each other later at a dancing class and maybe achieving a durable union. The play is filled with multiple snapshots (repetitions) of the same moments in the characters' relationship/friendship, with each producing different outcomes. Each snapshot is a different universe, a different possibility of the same event that the characters jump back and forth between. Payne's attempt to show all the possible ways in which Roland and Marianne's first

encounter could have turned out causes time to repeatedly go back to the beginning to let events unfold differently. This temporal fluctuation goes hand in hand with spatial fluctuation as the audience, in its travel between different possibilities, is constantly transported to and from the barbecue party, a dance class, and a small flat in London. This travel through space, however, does not physically occur on stage; rather, the audience learns through the characters' dialogue that the location of the story has changed. What Payne does is present a series of repeated snippets with different outcomes in which time and space are employed in such a way that they function as rubber bands stretched by the playwright to the extent that he would permit, and then released to return to their original place.

In Background and *Comet Hunter* time is used as a focused subject in the plot rather than the ether that the story lives within. *Background* is based on the true story of the cosmologist Dr. Ralph Alpher. Mimicking the study of the origins of the universe, the play moves backwards to trace the path of its scientist protagonist whose research provided the mathematical proof of the existence of Cosmic Background Radiation long before technology was capable of doing so. Twenty years later, after Arno Penzias finds the actual radiation, which brought him the Nobel Prize and worldwide recognition, Ralph suffers a heart attack. It is from this moment that his memory takes over and traces backwards through his life to its beginning. This act of remembrance turns into an act of recognition as the cosmologist views the past from his present situation in order to comprehend his 'now'. The audience sees the plot develop in the past through the characters' revisiting of it on the stage, while being constantly referred to the present. The present therefore becomes an evolving, dynamic organism trapped in a growing web of past events that expands parallel to it. This gives the setting of the play a sense of double time frames developing one alongside the other, as well as a multiple stage

space. While we see characters in a hospital room in Grant Street in the present, we also see them in the past, moving from a conference room to a restaurant on 4th Street and from there to an office in George Washington University. This allows time and space to become visible characters with multiple personality traits.

Comet Hunter also uses the act of remembrance as an effective trick to make the clock tick forwards, backwards, or disorderedly. The protagonist is the first recognized woman astronomer in history, Caroline Herschel, born 1750. With the help of a character called Time we see Caroline's present unfold on stage, whilst also witnessing her past open up in front of our eyes. Time is always present on stage, unseen by all the characters but Caroline, turning the clock's hands backwards and forwards according to Caroline's mental and emotional states, revealed to us through their one-to-one conversations. At different occasions in the play, the present suddenly pauses while time is still flowing, but this time in the past as we have entered Caroline's mind to see one of her memories acted out on stage. Over the course of the play, Time also informs us of the events that will happen either in the near or distant future. Those events that respond to near-future situations are enacted on stage later in the play and therefore become our present. This process of the future becoming the present happens alongside the process of the past becoming the present. Caroline's flashbacks into the past, in other words, make the present become future, while Time's foretelling of near-future events will actually make the future become present. Additionally, the far-distant future events, for example the reappearance of Caroline's comets in the late twentieth century, also become past relative to the audience, as it has seen those events happen in the past, which is, in fact, the far-distant future relative to the characters in the play. This complex relationship between different time frames disrupts the play's space frame, putting the audience in a teleporter that instantly transports them back and forth between

Hanover, Bath, and Slough.

These processes of past becoming present and present becoming future happen in almost all the contemporary science plays discussed above. In these plays, the present is not the most important part of time simply because it delineates past from future. The present is, in fact, the convergence point of the past and future. These two forms of temporality do not happen or are not illustrated as corresponding to the arrow of time; rather, they exist simultaneously by haunting the present, a present that does not have priority only due to its being immediately accessible. The past and the future occupy the present of the scene and can thus become instantly accessible. For there to be a sense of a story lost in the continuum of time, a sense of shared 'lostness' in space is needed. In contemporary science plays, the here and there also constantly turn into each other and form a unity. In these plays, the Newtonian linear rational perception of the passage of time and the change of space are taken hostage by the Einsteinian flexible and relative sense of time and space.

2.2 When an Armadillo Tells Stories: The Nonlinearity of Narrative

H. Porter Abbott writes that "Narrative is the principle way in which our species organizes its understanding of time… As we are the only species on earth with both language and a conscious awareness of the passage of time, it stands to reason that we would have a mechanism for expressing this awareness" (3). Contemporary science plays also seem to be following the same line of thought. As discussed in the previous section, in this genre, the stage is turned into a place where past, present, and future constantly flow in and out of each other, and an understanding of the play depends on an understanding of the union of all these units. The narrative structure of science plays

also reflects this pattern. The stage is populated with a number of events that form the fragments of the narrative that the play contains. These events are scattered throughout the plays' wide spectrum of non-chronologically ordered time frames, and therefore shape a discontinuous fractal narrative with no linear sequence. In other words, rather than forming themselves into a narrative with a beginning-middle-end structure that expresses underlying causal laws, the events fracture the continuity of the plot. The fragments of the narrative remain connected but the connections are looser and more discontinuous than they would have been if a chronological order were to be applied. The narratives either jump from one temporal point to another or suddenly disappear when interrupted by a fragment from another narrative, to leap and reappear later in the play or to do both. This situation is similar to the quantum leap, where particles disappear (or jump) from one location and reappear again at another location without traversing the intervening space. At the subatomic level also, the particles remain connected in a sense; they do not leap out of the nuclear orbit but the connections are fragmented and nonlinear.

This discontinuous narrative structure leaves the work of interpretation and association to the audience, demanding more active participation on its part than is traditionally called for. A great deal of mental input is required from the audience in order for them to follow the course of the narrative through all the leaps across time and space, and to draw correct connections between its fragments. It has to juggle the great amounts of information coming at it from different time frames and continuously add to or revise its understanding. To clarify the point, an analogy can be made with a sushi-go-round restaurant where the customers sit behind a rotating conveyor belt picking their selections from a steady stream of plates with the sushi moving along the belt. Similar to the customers in the sushi-go-round, the audience in the theatre is presented

with a steady stream of fragments, each belonging to past, present, or future over the course of the narrative. However, unlike the sushi-go-round customers who can pick their own selections, the audience is forced to attentively gather up the right fragments, arrange them in a causal order, and highlight patterns of connection. In *Arcadia*, *Bone Portrait*, and *Einstein's Project*, for example, not only are the fragments of the narratives presented in the temporal and spatial dimensions in which they take place, but also in the course of other narratives in other settings. In *Arcadia* the audience is required to fill the gaps in the historical narrative with constant reference to the literary critics' reconstructed version of it, and vice versa. In *Bone Portraits*, although narrative transitions obstruct the audience's immediate access to the complete draft of Clarence's narrative, segments are gradually added to it by revealing glimpses of his story through other characters' dialogues (Josephine, the inventor, and Nana) in other time frames. The same process repeats for other narratives of the play. In *The Einstein Project* the audience is presented with juxtaposed glimpses of the ways in which five scientists reacted to the construction of the atomic bomb. Due to the abrupt, rapid time shifts, the narratives form themselves into a series of parallel episodes that all go along with each other. This enables the audience to immediately and constantly compare the decisions Einstein makes against those made by his colleagues. These comparisons, in fact, paint the portrait not only of Einstein, but also of his colleagues.

In *Moving Bodies*, *Comet Hunter*, *Background*, *Now, Then, Again*, and *Constellation*, the breakage from the Newtonian illusion of absolute time is clearly reflected in their single-narrative plots. The narratives leap from one layer of time to another, folding the present back or ahead, to suggest a glimpse of some indirectly corresponding part of the past/future, itself in multiple fragments that are not rendered as continuous or whole. The arrangements of the events both in the present and the

past/future are loosely chronological, interrupting both cyclical time and linear narrative whilst allowing past and present to float in relationship. In *Moving Bodies* and *Comet Hunter* the narrative unfolds in the minds of the protagonists, Feynman and Herschel, racing rapidly back or ahead in the order that the characters' minds dictate. The audience sees their biographies unfold on stage in the form of a series of random frames cut from different points in their lives with no chronological order. The minds of the characters, in other words, stretch the narrative across time and constantly release fragments which, rather than being chronologically connected, are psychologically ordered by the forces of characters' immediate environment. The audience, therefore, is required to pick up these fragments once they are released and correctly place them in the narrative's temporal spectrum. In *Background* also, the mind of the play's protagonist, Ralph, narrates the story. However, unlike the other two plays, the past fragments of the narrative unfold on stage chronologically, though their linear order is altered by the constant appearance of fragments of 'now'. These temporal leaps made by the narrative create an irregular, seemingly separate set of fragments, the connections of which must be established by the audience.

The unusual temporal structure of *Now, Then, Again* and the abrupt rapid time shifts in *Constellation* make 'fragment hunting' a puzzling experience for the audience. The plays' narratives begin in the present and shift without explanation or transition to the past/future and back to the present. In *Now, Then, Again*, this shift takes place through objects and events that have made their way from the future into the present (such as an engagement ring, a burnt-out light bulb, a couple ice-skating) and in *Constellation* through a rapid succession of scenes replaying the same events. This turns the plays into a chaotic jumble of narrative fragments that render no logical connection. All the audience can do, in the case of *Now, Then, Again*, is wait for the moment when

in the forward movement of the narrative towards the future the fragment foretold in the past is reenacted on stage as part of the 'now' moment. That is when the narrative itself places the fragment in the right temporal location and then creates the logical connection. In the case of *Constellation*, however, the narrative's constant leaps from the past to the present and vice versa do not yield any linear account of the plot since there is not one. The audience sees only a group of recurring scenes in which the details, except for basic fixed points (the name of the characters and their occupations), change after every repetition. In its constant travel to the past, the audience watches these repetitions in the hope of detecting some common details, other than the fixed points, to complete the narrative, but the attempt is futile. Every leap of the narrative into the past generates a new set of fragments, which are irrelevant to the fragments already shown or yet to come.

Similar to *Constellation*, the narrative in *Copenhagen* makes a fruitless effort to complete itself by repeatedly jumping back and forth in time, but every travel into the past only postpones and eventually stops the process of completion. The audience follows the track of the narrative's temporal jumps to hunt the much-needed fragments to complete the puzzle, but since the characters' memories constantly fail them, every temporal travel only adds new fragments without completing the stream of previous fragments.

In Arthur Kopit's *Y2K* and Jonathan Sherman's *Evolution* (2002), two science plays about the negative consequences of technology, time does not move ahead nor does it move backward, however the narratives consist of fragmentations. *Y2K* juxtaposes two narratives of the same story, revolving around the life of a professionally and personally flourishing married couple, Joseph and Joanna Eliot. The first narrative is an account of the story enacted on stage by the couple. The second, however, is a told

one narrated by the play's narrator, Costa Astrakhan, a nineteen-year-old computer hacker who in cyberspace turns Joseph and Joanna into sexual deviants. The linear flow of the enacted narrative is repeatedly interrupted by the appearance of Astrakhan on stage to tell the audience directly his own version of the story (the told narrative). This constant interjection of the fragments of the told narrative into the enacted narrative makes them unfold in an episodic fashion. The audience watches the disappearance and reappearance of the narratives on stage and follows their track to eventually create a linearly ordered pattern. In *Evolution* too, the same fragmentation takes place, but rather than by the constant interjection of another narrative, by the regular appearance of two characters, the storyteller and Gina, a Hollywood femme fatale. The narrative of the play centers on Henry Gosh Hamilton's quest to know what he wants in life. He is a Darwin scholar with no knowledge of popular culture, who after befriending the non-academic brother of his girlfriend, Hope, loses his intellectual faith and cultural chastity to the power of television and enters the entertainment industry. The interruption of narrative continuity by the constant appearance of the storyteller and Gina onstage makes the audience feel involved in a hide and seek game with a naughty boy, but on a stage in a theatre rather than in a backyard.

The constant intersection of the two narratives of the science performance *On Ego*[31] gives the play an impression of discontinuity and nonlinearity. Gordon and Broks open the play with a fragment of the first narrative in which Alex, a neuroscientist, wants to illustrate, in a scientific lecture, that there is no ego, no 'I' behind the face by conducting an experiment using a teleporter. The procedure involves transmitting Alex by radio waves to another place. The original body should be automatically eliminated but after twelve successful operations, the machine suddenly malfunctions. Alex is

[31] Although *On Ego* is written by an Irish playwright, Mike Gordon, the co-writer, Paul Broks, is British, which places this play within the scope of this research.

transmitted to dinner with his wife, Alice, but is not simultaneously eliminated in the teleporter. He is therefore duplicated, and while the 'replica Alex' immediately starts acquiring different experiences and memories in the second narrative, the 'original Alex' struggles to decide whether or not he should destroy one version of himself. The logical sequence of the fragments in both narratives is disturbed by their constant intersection. In their continuous natural flow towards completion, the narratives have to make constant frog leaps over each other's fragments as they come along, demanding the audience's active participation to piece together these narrative jumps.

As this discussion shows, in many contemporary science plays this quantum assault on the continuous and linear motion across the universe of the atom often results in plots that no longer depend on logical sequence. They create a set of narratives with restless legs that tend to constantly jump around and shift in time to form structures that, rather than being straightforward, as in traditional theatre, are far more labyrinthine and webbed.

2.3 Yin-Yang:[32] A Doubled Difference Within

As mentioned earlier, Bohr's principle of complementarity considers incompatible and mutually exclusive concepts, namely waves and particles, essential to an understanding of the subatomic reality, due to their unity being an intrinsic property of quantum particles. Cotemporary science plays too, seen through the lens of new physics, encompass a paradoxical complementarity, a doubled difference, within themselves. In this genre, the science play practitioner sees the theatrical work

[32] In 1947, Bohr supervised the design of his own coat of arms, which featured the Chinese Yin-Yang symbol and a motto in Latin: "*contraria sunt complementa*", meaning "opposites are complementary".

containing a set of 'wave functions' in which two essential elements are at work whose paradoxes and inconsistencies keep them in a complementary state. In other words, the science play practitioner incorporates two mutually necessary components into a larger whole, which are oppositional if applied individually but complementary if considered together, due to their unity being essential if we are to have a complete description of the whole. By doing so, the plays create a universe similar to the subatomic one, wherein things that appear to be contradictory and in opposition to one another are actually, like waves and particles, one another's accomplices.

The contemporary science play practitioner places these apparent dichotomies within an interanimative field in which they are accelerated and quantified into new shapes and structures. In *Comet Hunter*, *Remembering Miss Meitner*, and Christopher Hampton's *The Talking Cure* (2002) this duality is manifested in the collaboration and interaction between women and men, as two opposite forces, to produce knowledge. In *Comet Hunter*, Caroline's collaboration with William, her successful astronomer brother, resulted in the latter's discovery of the planet Uranus, and the former's observation and discovery of many comets and nebulae. They also conducted several Deep Sky Surveys together, which led to the publication of three catalogues containing detailed descriptions of thousands of nebulae and clusters of stars. In addition, William did not begin his career as an astronomer until after Caroline joined him in England to assist him. Caroline also developed her interest and skill in astronomy as a result of her collaboration with William. This interdependence of two opposites, a man and a woman, to produce the same thing, knowledge, brings Ying-Yang into the world of *Comet Hunter* by showing that opposites exist to complement and combine each other in form of a unity.

The same unity of male/female opposites takes place in *Remembering Miss*

Meitner, in which Friedman presents the discovery of nuclear fission as the offspring of an essential collaboration between female and male scientists. He brings Meitner and her two male colleagues back to life to show that scientific discovery can only be arrived at through the energy created by the friction of two opposites. A woman and a man scientist form themselves into a unified yet contradictory energy, that is, nuclear fission, which although it splits things apart, it is the result of unification and integration.

The Talking Cure, on the other hand, explores the male/female duality in the domain of psychoanalysis. Hampton tells the story of Carl Jung's love affair with one of his patients, Sabina Spielrein, who later became one of the first female psychoanalysts, and depicts the impact that this relationship had on the expansion and flourishing of the field of psychoanalysis. Deploying psychoanalytical techniques, Jung finds the cause of Sabina's problem – the childhood association of sexual arousal with parental punishment – and transforms her from an aggressive, disturbed woman into a rational, stable medical student and later practitioner. The erotic aspect of the relationship also enables her to have a lived knowledge of sexual experience that contributed significantly to her study of psychiatry and human sexuality. Jung's treatment of Sabina and his relationship with her also played a significant role in the development of his theories of psychoanalysis. Not only was she the first patient on whom he successfully tried psychoanalysis, but also she assisted him with his research in word associations and suggested to him the 'anima' theory. Additionally, Spielrein's case appears to be at least part of what motivated Jung to initially contact Sigmund Freud, as a result of which the rupture between student and mentor intensified, which enabled the former to travel deeper into the unconscious. Here, Hampton seems to suggest that the fusion of two opposites, a Swiss Aryan male doctor with a Russian Jewish female patient, is what lies at the heart of Jungian theories in psychoanalysis.

In *On Ego*, *The Effect*, and Peter Parnell's *Trumpery* (2007), the complementarity of opposite properties of the same thing is explored with relation to scientific theories. In these science plays, the science play practitioners discuss two opposing scientific approaches towards a concept in such a way that they form themselves into two mutually incompatible yet necessary components of that concept whose unity constitutes its definition. In other words, the science play practitioners' intended definition of concepts of identity (*On Ego*), love (*The Effect*), and evolution (*Trumpery*) are formed when their opposing descriptions, as their essential components, come together and form them into unified wholes. 'Bundle theory' and 'ego theory' are the two scientific views that dominate the central debate in *On Ego*. Alex starts off as a committed bundle theorist, believing that there is no ego, no self behind the face and that the self is only a story told by our brain. However, when his replica begins to live the life he would have lived, he begins to feel like an ego theorist; he feels that his unique 'I', his real 'self', his 'central core' has been stolen from him. Throughout the play, Alex constantly shifts from an objective scientific view of himself to a subjective view as he reacts to his experiences. He moves from what his logic tells him to be to what he intuitively believes himself to be, and vice versa. This double-sidedness of self is skilfully depicted in the final scene, in which, in the form of a brain soliloquy and with the help of voiceovers, Alex's voice as a bundle theorist is mixed with his voice as an ego theorist. Simultaneous to this voice play, on the screen behind Alex, the bundle of thoughts and feelings in Alex's brain is intercut with images that map the history of Alex's relationship with Alice. Through Alex's collision of subjective and objective views of himself, Gordon and Broks form these two opposing descriptions into a single whole and name it the 'human sense of self'.

The Effect also follows the same trajectory as *On Ego* does, but instead of

identity places love in the orbit of the brain. The two theories surrounding the mind-body debate in psychology form the basis of the play: materialism (mind is just a byproduct of the material function of the brain) and dualism (mind and body exist as separate entities). Prebble places these theories within the context of love and how we can be sure of what we are feeling: does love occur as a result of chemical or biological changes in the brain or is it a genuine feeling that starts from the heart? This duality is illustrated in the opposite explanations that each of Prebble's protagonists provides to justify the strong attraction they feel for each other. Connie, a psychology student, defines it as a chemical reaction only, while Tristan considers it a real thing, a strong and passionate emotion that he feels in his heart. Throughout the play, the audience is shuttled back and forth between these two views, ending with the impression that a chemical reaction and a genuine feeling together form the most complete description of love. Prebble seems to have shared her protagonists' sense of doubt and uncertainty towards the true nature of love, which impelled her to build a duality right at the heart of the play.

In *Trumpery*, Parnell weaves two opposing interpretations of the theory of evolution into the fabric of the play through dramatizing the well-known story of Charles Darwin and the other theorist behind the theory of evolution, Alfred Wallace. The play opens with Darwin reading Wallace's letter and essay setting forth almost exactly the theory of evolution that Darwin had been working on for the past twenty years. Out of fear of losing fame and recognition, Darwin decides to publish a paper together with Wallace that will hardly get noticed, firstly to make Wallace's findings public, and secondly to give himself enough time to publish *On the Origin of Species* (1859). The juxtaposition of opposites in the play takes place when Wallace and Darwin meet each other in Act 2 to discuss 'what happened'. Darwin, who views the world as a

place of harsh competition in which only the fittest will survive, and so ignores Wallace's equal right to originality, expects Wallace to do likewise and fight back. Wallace, however, expresses his sincere gratitude to Darwin for putting his essay together with his, because to him the survival of the fittest means that "in order for our species to survive, we must – and our very biology knows that we must – cooperate. Not fight. Mutual aid, Charles. It is not to the individual, but to the tribe that we must look" (Parnell 48). Here, through the medium of his play, Parnell provides an opportunity for the theory of evolution to be taken as expressing two opposing views as to the way human nature should be conceived of: as cruel and selfish or as kind and cooperative. The fact that a theory has the potential to reconcile the paradoxical interpretations of its own originators within itself reflects the duality inherent in the evolutionary description of human nature.

Mark Ravenhill's *Faust is Dead* (1997) and Jennifer Haley's *The Nether* (2013) deal with the inescapable duality of the real versus the virtual that characterizes modern society's perception of the world. Creating a dystopian near future which is dominated by complex computer networks, these science play practitioners set their characters within a society of simulation where reality and virtuality are merged into one, so that it is no longer possible to distinguish them. Pete in *Faust Is Dead*, a science play that explores the gap that technology has created between abstract thinking and lived experience, can only bear experiences when looking through the lens of a camcorder because it makes them more *real*. Donny is a teenage boy whose only medium of communication to the world is the Internet. He cuts his flesh with a razor and posts the images of his lacerated body on his homepage. These images are transmuted into codes through which he communicates his message to the world and make human relations. For Pete and Donny, the virtual becomes real and the real becomes virtual and this

duality is what defines their perception of the world. In *The Nether*, Haley creates a virtual new wonderland in which reality and virtuality are interchangeable. In this world, users log in, choose an identity, and indulge any desire in a beautiful, and very real, Victorian country manor house. They are asked to first rape and then cruelly murder four beautiful charming children that re-spawn after each murder. Things get even more complicated when these children become the avatars of adults who have logged in from the real world. With a click of the mouse, the in-world life and self of the characters turn into virtual ones, which are so real that make the boundaries between reality and fiction no longer recognizable. In the realm of these plays, the perception of the world has a dual nature, both real and virtual.

Gunderson and Giron in *Emilie* and *Moving Bodies* imagine heart and head as not separated according to the conventional polarity, but rather complementary, in a union that defines their protagonists. Under the masks of scientists, Emilie and Feynman exist as two people who not only passionately think but also passionately love. In Gunderson's play, Emilie's life as a scientist runs parallel to her life as a lover. Different stages of her scientific life are marked by the presence of one or multiple men whom she loved and used as source of inspiration for her work. However, among all the other men, it is Voltaire whose love sets forth a unifying theory of head and heart. Gunderson imagines the two as kindred spirits, almost isolated from the rest of the world by their power to think and contemplate. They are happy to walk out alone together into the exiting new intellectual frontier opened up by Newton's new conception of the universe, and along the way bring love, sex, and passion. The result of this relationship between two intellectual colleagues and two passionate lovers for Emilie is a paper on the nature of fire and a translation of Newton's *Principia*. This head/heart duality is portrayed through Leibnitz's formulation of force, $F=mv^2$, which Emilie tried so hard to prove. In

the world of mathematics, V stands for velocity only. However, in the world of Emilie, it stands both for velocity and for Voltaire. This putting together of a 'force for thought' and 'a force for heart' in one piece (V) emphasizes the double-sidedness that forms the basis of Emilie's existence.

"Sex and science don't mix" (Giron 44). This is what characterizes the scientific mind of the time when Feynman begins his career as a scientist. However, *Moving Bodies* portrays him as a man whose whole life was spent in attempting to find an equation that would integrate science and love. Giron locates this unity in his protagonist's life right at the beginning of the play, when at the 1933 Chicago World Fair the teenage Feynman is introduced to both women and science. There he watches, hot and bothered, Sally Rand's nude dance, and the latest scientific inventions all together in one place. This is where his brain starts to catch up with his body, "Never seen so many atoms so well put together… jiggling… hot… I really understand now 'bout atoms lookin' for partners… to… rub against. For the first time" (15). Later in the play, his desire to be both a scientist and a lover reveals itself in the most confounding and illogical decision a scientist would make: marrying a dying woman. Despite the fact that he knows Arlene is dying from tuberculosis and is warned against having sexual relations, and against the strong objections of his parents and the clear terms of his Princeton scholarship, which forbids marriage, Feynman decides to betray his defining characteristic as a scientist, rational thinking, and listens to his heart and marries Arlene. Giron highlights this unity of head and heart in the protagonist in a scene in which, while Feynman and Arlene are kissing each other, Sally Rand appears behind the bed and forms the shape of an atomic bomb explosion with white ostrich feathers. This scene portrays Feynman as a man with two complementary faces: as a scientist and as a lover.

In *Copenhagen*, the uncertainties surrounding Heisenberg's motivation for

visiting Bohr integrates two sets of contradictory interpretations – one portraying him as a hero and the other as a villain – into the totality of what is knowable about his intentions. Throughout the play, the borders between these interpretations constantly shift; we are continually switched from an admiration for Heisenberg due to his attempt to persuade Bohr to stop the Nazis' nuclear program by a joint refusal to an antipathy stemming from his intention to pick Bohr's brain about the Allied nuclear program simply because he has placed his ultimate moral allegiance with German culture. Neither interpretation can be fully separated from the other and the interference is the result of the collision of different drafts that simultaneously reinforce both perspectives. This uncertainty eventually results in the depiction of Heisenberg as both a hero and a villain simultaneously.

Wertenbaker also inserts the same hero/villain dichotomy into the body of her science play *Laws of Motion* (2004), but instead of Heisenberg chooses Galileo as her victim. Maria Celeste, Galileo's gifted child, a nun who shared her father's passion for scientific investigation, is the source of this duality. After her father's recantation of his blasphemous philosophical views, Maria Celeste rejects him, interpreting his decision as an act of betrayal both of truth and of himself. Galileo, on the other hand, considers his act a heroic one, thinking that by choosing life over death he will "discover more hidden folds of nature" (Wertenbaker, *Motion* 87) and will therefore contribute more to human betterment. This contradiction runs throughout the play, expressing the devil/hero dual nature of Galileo.

The contemporary science plays discussed above create polarities, defining one concept, view, or interpretation to shape the plot, and setting up various possibilities and outcomes within it. These contemporary science play practitioners break oppositional concepts down, open them up and merge them, deconstructing them in such a way as

that the audience is left with a quantum flux of links, in which contradictions melt into one another and become one, and in which nothing is as it seems.

2.4 No Truth is Truth

Marianna Torgovnick explains that "We value endings because the retrospective patterning used to make sense of texts corresponds to one process used to make sense of life; the process of looking back over events and interpreting them in light of 'how things turned out'" (5). This expectancy of achieving a final perspective expresses the Newtonian desire to reach an absolute frame of reference by which causal laws can be established with certainty. The new physical reality, however, makes a sense of closure, completion, and certainty unachievable. In contemporary science plays the privileged and absolute frame of reference that characterizes traditional authorship is avoided. Instead of reinforcing an authoritative voice and perspective, science play practitioners place themselves in a position of involved uncertainty by generating multiple voices and setting them in conflict. They put their voices in relation to other different voices in their plays, and create a complex web of possibilities, without resolving them into definitive forms. As Margaret Atwood puts it, "Writing is self-less in the same way skiing is, or making love… your attention is focused not on the self but on the thing being made, the thing being seen" (qtd. in Strehle 223). For science play practitioners, the play is a web of intricate voices whose priority over each other remains indeterminate. This polyphony causes the plays to remain open, uncertain, and unsatisfying with regards to the audience's wish for fulfilled promises and completed outcomes. They create new models of theatrical realities where different possibilities, outcomes, and perspectives, with equal credibility, come together in dialogue to mimic the necessary uncertainty that

characterizes the contemporary sense of physical reality, the fact that reality is a subjective construct and absolute knowledge is unattainable, and that all we have are probabilities and nothing more.

Giving priority to the act of observation, science play practitioners perform a less biased form of authorship than earlier playwrights and theatre practitioners, aware of the relativity of perspectives and the plurality of alternative versions of reality. In *Y2K*, for example, the act of observation changes the reality observed. The version passed through the filter of Astrakhan's subjective interpretation of reality races against Joanne and Joseph's enacted account of it to win the audience's favor. Due to the credibility of both versions, however, the audience's certainty becomes shifting and elusive to the extent that both accounts become true and false simultaneously. This introduces a systematic uncertainty into the play, which makes each version carry traces of reality, but no one of these traces is definitive.

Background raises the question of indeterminacy through the device of the discovery of Cosmic Background Radiation. Who is the true discoverer? Alpher who provided the mathematical proof, or Arno Penzias, who actually found the radiation? In her journey backwards through Alpher's life, Gunderson only provides random hints as to the role each of the scientists played in the discovery. However, she casts the shadow of uncertainty over the play by not taking sides with either of them and letting the audience's observations shape the reality. Gunderson's other scientist character also fails in her quest for certainty. Emilie's final answer to the mystery (love or science) is that there is no answer. Despite the fact that Gunderson seems to be in favor of the unity of both, Emilie herself is incapable of putting an end to the sequence of her questions, as "For all your knowing, you are blessed with more – questions. And all the answers may not come – but asking makes us last. And that makes you… done and never done"

(Gunderson, *Emilie* 99). Gunderson does not restrict the audience to a binary choice but rather offers them a host of prospects; they are free to make up their minds: Love? Science? Or Both?

In *Copenhagen* reality is presented as a subjective construct and each character is his/her own measure. In an attempt to answer the question 'what happened and why', Margarethe, Bohr, and Heisenberg each try to make reality conform to their agenda. However, as the characters' interpretation of reality is carried out from a specific point of view in time and space and from the one particular viewpoint of a particular observer, they cannot agree even on the time and place of the meeting, let alone on what was said. As a result, different versions of the same reality are presented, all of them to a greater or lesser extent credible. The audience's certainty of one version is therefore immediately put into question by another version, and so on. This process of constant rejection piles uncertainty upon uncertainty and turns the play into an open-ended quest with no definitive end, and therefore an enactment of the observer effect and the uncertainty principle.

In *Laws of Motion* Galileo's observation of himself as a truth-seeker and his daughter's perception of him as a truth-betrayer remains unresolved at the heart of the play. In Wertenbaker's world there can be no static interpretation, but only a polyphony that puts reality in a communicative flux of multiple perspectives. *The Effect* also leaves the conflict of opposites stuck deep within its audience. Throughout the play, descriptions of reality constantly shift from 'real love' to 'artificial love', without meeting at a certain point. The audience's version of reality is therefore full of gaps, in flux, contingent, and uncertain. Payne, however, is the most generous contemporary science play practitioner discussed in this chapter; he provides his audience with a wide spectrum of possibilities to choose from. Enacting the idea that "at any given moment,

several outcomes can co-exist simultaneously" (Payne), the audience is located in the ambiguous space between an enormous number of different/contradictory versions. Roland and Marianne, for example, meet at the barbecue in three different ways. Four different versions of who betrayed whom, with whom, and to what extent are presented. The tragic element of the play (Marianne's death) is shown at least three times, twice tragically and once happily. These multiple perspectives and unresolved contradictions allows Payne to ensure that, by the end of the play, the tastes of any type of audience are fully met.

In *On Ego* the two storylines are merged to the extent that the boundaries between fact and fiction are dissolved. The audience is trapped in a teleporter whose only destination is the land of uncertainties. It is almost impossible for them to distinguish the original Alex from the replica, and the more accurately they know the replica, the less accurately they know the original, and vice versa. The soliloquy at the end of the play feeds their sense of uncertainty even further. This confusion leaves the audience having to choose one of two positions: one that the self consists of its properties only, and one that it should be described in terms of psychological construction and complexity.

Sherman posits a radical indeterminacy in *Evolution* by depicting his protagonist's quest for purpose and direction in life as fruitless and in vain, under the interrogation of his faculty advisor: "What do you *want*? From school, from life, from me, from yourself. What's something you really *want*?" (Sherman 12) Henry admits that all he really wants is to know what he really wants. His unexpected career in the entertainment industry is also an attempt to answer this question. After his huge success in the movie industry, Hope asks him the same question, "What do you want?" (45), to which he has no answer. He eventually dies in a car accident wondering what he wants

from life. Sherman creates a vacuum of uncertainty that sucks the audience in, implying that the question “why are you here?” is “no more than a false promise a hollow wish, a prayer if you will”. Then as if it has been a bedtime fable to a child, he teases, “sweet dreams” (50).

Contemporary science play practitioners’ fascination with the uncertainty that haunts the interior of quantum reality demonstrates that we have entered the domain of what Bohr describes as “essential ambiguity” (696), where there is no foundation, no bottom, no grounding, unless we decide to describe chaos, disorder, and collapse as such.

2.5 Spooky Connections

The inaccessible and invisible world of entanglement in quantum mechanics, as we have seen, describes entities that no matter how far they are instantly connect with each other. Maybe this is because everything is connected, there is no separation, and within the realm of quantum flux there lies a hidden web of entangled connections. An entanglement of this kind is what lies at the heart of contemporary science play practitioners’ fascination with making characters, human motives and perceptions, and worlds become entwined, regardless of whatever vast distances may come between them. These science play practitioners create seemingly disconnected realms in which characters, motives, and ideas are located in different temporal and spatial scales, and interact with one another within a web of entanglement and hidden connections. The interdependence of one realm with another is sometimes so strong that one cannot exist without the other, such that the entanglement defines their very existence.

In science plays that interconnect spatially and temporally distanced realms, the

entanglement follows a complex process of message exchange. The realm that is being enacted on stage sends constant messages, in the form of codes, to the absent realm, to immediately connect with it. This process of message exchange between two distanced realms sometimes creates such an interrelated connection between them that the existence of one seems implausible without the other. In *Moving Bodies* and *Comet Hunter*, for example, Feynman and Caroline can immediately connect to distanced points in time and space through the device of memory. They are at present involved in present-day actions, when suddenly a trigger is released which sets off their brains' process of backward movement in time. Feynman's conversation about lust and love with Oppenheimer at Princeton, for instance, acts as a code communicated to the brain to immediately connect him to the past, where he sees Arlene on the beach, wearing her two-piece bathing suit and waving at him. This memory triggers another temporally/spatially different memory in which, at the Feynman house, the family expresses their disapproval of their son and Arlene's marriage. These distanced realms are so quickly connected that the audience sees the three scenes at the same time. In *Comet Hunter*, when William, in Slough, informs Caroline of his marriage, her memory immediately connects her to the past where she is told by her father in Hanover that due to her physical condition (her body had not fully grown due to typhus) she would never be able to get married. Her mind travel then instantly takes her to the time when as a young woman she admired her brother's charm and handsomeness.

In *The Einstein Project* and *Bone Portraits*, this message exchange sees a number of distanced realms become entangled. The audience sees different characters at different points in time and space constantly and immediately entangled through a set of events that respond to each other thematically. In *The Einstein Project*, a scene in Farm Hall in Cambridge, with German scientists assuming Einstein's innocence due to him

being their friend, is immediately entangled with a scene in Switzerland, in which Von Laue and Einstein meet for the first time. At several points in the play, the presently enacted scene gets immediately entangled with a different setting when the Patche News announcer, along with newsreel figures, appears on stage reporting a piece of news thematically related to the scene. *Bone Portraits* makes the immediate connection between distanced realms through the device of a narrator. The narrator, Edison, introduces a topic in the present, which is instantly connected to a scene in the past in which that topic is being enacted. For example, the scene in which he explains America's obsession with x-rays when they were first discovered gets immediately entangled with the past, where this obsession is demonstrated at the Chicago's World Fair in 1893. This narratively charged message exchange is the main entanglement device in the play. Similar to *Moving Bodies*, however, distanced realms become entangled by the simultaneous enactment of two seemingly separate scenes; we see, for example, Clarence and Edison discussing the mechanism of the x-ray machine parallel to Nana and Josephine talking about the impact and importance of this discovery.

Kopit also uses the device of a narrator to connect distanced realms. For the duration of *Y2K*, the sudden interruption of the natural sequence of Joseph and Joanna's narrative by Astrakhan's remarks, as narrator, is designed to demonstrate exactly how to alter a person's life in cyberspace. For example, in the scene in which Joseph is being interrogated by two FBI agents about the information on his computer, Astrakhan's sudden and constant appearance to explain hacking techniques leads to their realms becoming instantly entangled. Astrakhan's realm also instantly connects with that of the couple through his immediate account of the same event in their lives that has just been enacted on stage.

In other science plays with dual time frames, the entanglement between

distanced realms takes place through the similarities/differences that the science play practitioners draw between the past and present characters. In *Arcadia*, for example, Stoppard connects two epochs, two hundred years apart, through the themes of sex and love. The play opens with a conversation between Thomasina and Septimus over "carnal embrace" (1-4). As the plot unfolds, the historical and modern characters are, to different extents, entangled in sexual intrigues: Lady Croom and Septimus and Lord Byron and Mrs. Chater in the past, and Chole Coverly and Bernard in the present. The theme of love also develops alongside this: Septimus and Thomasina fall in love with each other in the past and Gus/Valentine and Hannah in the present. Once the past and the present characters become entangled with each other through the theme of love, they remain the same forever, as in the final scene we see them on stage dancing alongside each other. Valentine and Thomasina also become entangled with the help of mathematics. They are both very talented mathematicians who, in different eras, want to learn about the relationship between nature and the mathematician. This entanglement is underlined when Thomasina and Valentine's explanations of entropy, in the form of an indirect dialogue, speak to each other simultaneously across the ages (Stoppard 97-98). Valentine also happens to live in the same place where Thomasina used to live, the bedroom under the roof. This feature will be discussed in more detail in the following chapters in relation to other case studies.

In contemporary science plays the characters and the audience are trapped in a human-sized universe where unity is the result of opposition, polarity, and conflict; a constantly connecting and disconnecting universe where the structures of fragmentation and nonlinearity as well as entanglement and connectivity are revealed; a place where being human equals being uncertain and indeterminate in a world always splitting apart, fragmenting, and breaking down to match the reality that is hidden at its very base, at its

subatomic realm. Contemporary science plays, with their historical/fictional characters and events, and their complex discussions of scientific ideas or the ethical and social implications of the scientific endeavor, have fully engaged with the contemporary reality that defines our post-quantum world.

The detailed analysis of selected science plays presented in chapters 3, 4, and 5 brings to the surface not only their thematization and their modes for addressing science on stage, but also a better understanding of the contemporary theatrical perception of reality as influenced by new physics. Within the context of post-quantum reality, Chapter 3 discusses two text-based science plays in which science is at the margins; Chapter 4 analyzes two science-informed dramatic texts which place science at their center; and Chapter 5 explores two performance-based science plays in which science is communicated through dramaturgical and theatrical techniques.

Chapter 3

Science as Supporting Character

3.1 Introduction

The previous chapter set out the parameters of a new paradigm for the exploration of contemporary science plays within the context of the post-quantum perception of reality. This chapter uses the same parameters to discuss science plays but with more depth and with reference to two examples (Margaret Edson's *W;t* and Shelagh Stephenson's *An Experiment with an Air Pump*) that correspond to the first category ('science as supporting character') of the taxonomy presented in Chapter 1. In this category the centrality of science is undermined by the science play practitioners' focus on nonscientific issues that need a scientific context in which to be discussed and explored. In *W;t* and *An Experiment* the social and ethical aspects of science win over a metaphorical/detailed and accurate usage of science. However, despite the peripheral role of science in these plays, they still perfectly lend themselves to the analysis of the implications of new physics. Edson and Stephenson use the stage in such a way that the main features characterizing physical reality as described by new physics take control and create a theatrical experience that is non-chronological, discontinuous, contradictory, nonlocal, subjective, and uncertain. It seems that even those science play practitioners to whom the peripherals of science are more important than the science itself have not been immune to the changes that have occurred in the larger field of discourse. Their plays have also emerged from an interrelated thinking about reality in physics, culture, and literature.

3.2 Redemption and the Search for Completion: Margaret Edson's *W;t*

Margaret Edson's *W;t* offers a stark look at the sufferings and illumination of Dr. Vivian Bearing, a distinguished professor of seventeenth-century metaphysical poetry, who is a specialist in the Holy Sonnets of John Donne, and who is dying from stage-four metastatic ovarian cancer. Her oncologist, Dr. Harvey Kelekian, hopes to increase Vivian's chances of survival by including her in a protocol which involves eight cycles of full-dose chemotherapy to shrink her grapefruit-sized tumor. However, the treatment is not successful, and after eight months she eventually dies, after enduring a great amount of pain. *W;t* dramatizes the different stages in Vivian's treatment process, from her first day in hospital, her clinical interactions with doctors and the way she is treated by them, to the early and late symptoms of chemotherapy such as hair loss and vomiting, until her final moments on a hospital bed. Edson refuses to provide detailed and accurate descriptions of the medical science of the chemotherapy or cancer treatment; rather, she mostly focuses on the sufferings that cancer and its long painful process of treatment cause for the patients and the ways in which they are responded to by doctors. In doing so, she provides a theatrical commentary on the attitudes of medical practitioners towards the patients as well as a depiction of cancer and chemotherapy as ways of achieving redemption and salvation, especially for those people who have forgotten how to live like human beings; suffering reminds them that they need tenderness, affection, and human touch. This superficial imposition of the science on the play places *W;t* in the first category of science plays.

Edson's protagonist is a scholar who has devoted many years of her life to studying and teaching the work of John Donne but has tragically ignored the fact that his poems are a mixture of intellect and passion. "In chasing her academic dream",

Shepherd-Barr writes, "[Vivian] misses the crucial point about connectedness to her fellow human beings" (167). She is so buried in scholarly research that she has forgotten about human relations. However, the emotional and physical changes that she goes through as a result of her terminal illness send her on a spiritual journey, the result of which is the revival of her humanity, or as Edson explains, "her redemption" (Carter 26). In the very final moments of her life, Vivian "drops her bracelet and drops her cap and drops her gown and crosses the stage, she lets everything fall away from her… she [becomes] completely united with God" (26). Vivian's transformation is depicted in the play as an inevitable consequence of a radical change in her definition of wit. Her initial definition coincides with the seventeenth-century metaphysical poets' fascination with wordplay, literary conceit, and paradox, a capacity that suggests intellectual and verbal cleverness. However, during the course of her treatment, the concept takes on a new definition as a natural ability to perceive and understand. By the end of the play, the burden of 'knowing' is completely lifted from Vivian's shoulders and is instead replaced by this capacity of understanding.

The responses to Edson's play show two major approaches. Many critics have been so impressed by the intertextuality of *W;t* that it has become, as Wriglesworth points out, "an ironic 'play' of linguistic chemistry… that pulls the mind into an intoxicating web of allusions to John Donne's life and work" (214).[33] Other critics, however, have interpreted *W;t* within the context of medical practice. This perspective is based on the dehumanization of people due to the cultural and institutional orientations that have shaped attitudes towards illness.[34] However, Edson's play can

[33] See Madeline Keaveney, "Death Be Not Proud: An Analysis of Margaret Edson's *Wit*"; Rosette C. Lamont, "Coma Versus Comma: John Donne's Holy Sonnets in Edson's *WIT*"; and John D. Sykes, "Wit, Pride and the Resurrection: Margaret Edson's Play and John Donne's Poetry".

[34] See Catherine Belling, "Being with a Text: Teaching the Poetics of Medicine"; Therese Jones, "Ending in Wonder: Replacing Technology with Revelation in Margaret Edson's *W;t*";

best be understood as a complex fusion of all of the above. She uses the scientific and medical framework, as well as poetry, as an appropriate context in which to discuss a nonscientific, nonliterary subject: humanity's redemption is made possible by love, kindness, and tenderness. The audience watches Vivian's journey towards redemption on the stage as her past, in the form of memories, gradually unfolds within the context of metaphysical poetry and medicine. This multiplicity of frameworks and temporality is what makes it possible to discuss the implications of new physics in Edson's play.

3.2.1 Discontinuous Setting, Discontinuous Narrative

Like other contemporary science plays, *W;t* challenges Newtonian temporal and spatial absolutism and creates a microcosm of Einstein's curved space-time in which time and space, as relative and not absolute concepts, stretch to comfortably fit the time-space spectrum of the play, a spectrum that encompasses a time span as great as thirty years and as small as two hours, and space that spreads from a doctor's office to a university office and from a room in a hospital to a living room in a flat.

Similar to *Background*, *Comet Hunter*, *Emilie*, *Copenhagen*, and *Remembering Miss Meitner*, *W;t* breaks the thick walls of distinction between different temporal and spatial units through the device of memory. Edson deliberately avoids using linear time and space, in order to create a series of flashbacks that link Vivian's past to her present. More than half of the play happens in the past, taking the audience from Vivian's first meeting with Dr. Kelekian, at which he explains her illness and its treatment, to crucial moments in her personal and professional life. Through the scenes set in the present the audience follows Vivian's stream of thoughts and feelings as she reacts to and

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and Derek Amanatullah, "The Importance of a Physician's *Wit*: A Critical Analysis of Science in Medicine".

comments on the memories, and witnesses her emotional and spiritual transformation. The function of the flashbacks is to provide the audience with the necessary clues to understand the irony that has always characterized Vivian's life. As a literary scholar and a human being, she has placed a safe distance between herself and texts and relationships, using her wit as a linguistic defence against genuine textual and social engagement; a shield that, although it has established her as a "force" in her field (Edson 17), has in fact blinded her to truth. This simultaneous juxtaposition of past and present also enables the audience to compare Vivian's pre- and post-cancer selves, thereby underlying the emotional and spiritual transformation that she is going through as a result of her illness. Just like in other contemporary science plays, this temporal flexibility results in a discontinuous narrative structure that unfolds on stage as if through quantum leaps.

W;t opens in the present at the hospital, two hours before Vivian's death, with her directly addressing the audience and introducing herself as a literary scholar who specialize in Donne's poetry. She then begins to lecture her audience about the significance of textual analysis and linguistic accuracy. From here, the disruption of linear time and space and with it the linearity of narrative structure begins; on the turn of the sentence "I'll never forget the time I found out I had cancer" (Edson 7), Vivian's memory takes control of the stage and instantly takes the audience to Vivian and Kelekian's meeting at the latter's office, eight months in the past. The audience gradually realizes that the present scenes are in fact fragments of a long monologue, the linear flow of which is constantly interrupted by fragments of the past. Vivian is in the present giving her monologue when she recalls a memory; the play is then suddenly taken back in time to act out the memory onstage. Time then moves forward to allow Vivian to continue her monologue from where she dropped it. This causes the narrative

to be in a process of constant jumping from the present to the past and vice versa. However, the past does not unfold in a linear fashion either. The linear flow of the memories is also constantly interrupted by the fragments of the present that, in form of a comment or explanation in the monologue, suddenly pop up and force the past to make another jump, and therefore to unfold discontinuously. These narrative jumps continue throughout the play, revealing to the audience different slices of Vivian's life as a young student, an ambitious teacher, and a five-year-old girl.

Edson's depiction of time and space as relative to Vivian's act of remembrance and with no single unified pattern breaks down the narrative structure into a series of complex fragments that constantly leap forward and backward between different time units. This movement of the narrative from one 'time level' to another around the orbit of Vivian's memory figuratively enacts, in its structure, it might be argued, the quantum leaps that electrons take from one discrete energy level to another around the nucleus of the atom.

3.2.2 When Opposed Spaces Collide

"The play [*W;t*] is not about doctors or even cancer. It's about kindness, but it shows arrogance. It's about compassion, but it shows insensitivity", Edson explains in a 1995 interview with Charles Osgood for *Sunday Morning* (qtd. in Ruppersbury & Inscoe 136). She clarifies that these concepts in the play are conveyed through their opposites: "It's about everything that's the opposite of grace and kindness" (136). Edson develops *W;t* into a complex interplay between opposites – head and heart, failure and success, and to teach and to be taught – that eventually form themselves into a unified entity. This unification of oppositions occurs either within the protagonist of

the play or with reference to her; they are born within her, grow within her, and develop into integral parts of her to such an extent that her existence cannot be defined without them. Seen through the lenses of new physics, this aspect of *W;t*, namely the depiction of Vivian as a single entity within which multiple oppositions are reconciled, brings to mind Bohr's complementarity principle according to which at the heart of the inhabitants of the most basic level of the universe, particles, contradictory states, wave-like and particle-like behaviors, all coexist with each other within a single entity.

3.2.2.1 Head + Heart = Wit

W;t is most obviously structured around the opposition between head and heart. Through a series of juxtapositions, Edson shows the audience that Vivian is preoccupied with scholarly endeavor and is entirely untouched by human emotions. As a literary scholar and a specialist in Donne's poetry, Vivian is supposed to be concerned with feelings. However, she treats poetry with her head rather than her heart. This dispassionate approach to literature is clearly reflected in a flashback dramatizing her student days. In this scene, a twenty-two-year old Vivian is being chastised by her professor, Dr. E. M. Ashford, for having used an "unauthentically punctuated" edition of Donne's Holy Sonnets, in which "the simple meaning is sacrificed to hysterical punctuation" (Edson 14). She then criticizes Vivian for missing the point in Donne's poem and producing an essay that "is a melodrama, with a veneer of scholarship unworthy of you – to say nothing of Donne" (13). Ashford then tries to lead Vivian into a deeper meaning of the poem by conducting a close textual analysis, proving her point that scholarly analysis should be at the service of elucidating the theological depth of a work rather than only elucidating the sophisticated linguistic complexities. She

compares the line in the edition Vivian has chosen, "And Death – capital D – shall be no more – semicolon! Death – *capital* D – *comma* – thou shalt die – *exclamation point*!", to the one in Helen Gardner's edition that returns to the Westmoreland manuscript of 1610, the source for the poem: "And death shall be no more, *comma*, Death thou shalt die" (14). No semicolon, only a comma. She then explains that in the correct edition, the presence of comma instead of a semicolon clearly conveys the poet's true intention behind the poem; the fact that what separates life from death is merely a breeze, while the semicolon in the other edition sets a boundary between them (15). What she wants Vivian to learn is to go beyond the form and wordplay of a poem and to conduct a scholarly textual analysis according to the deeper meaning. The reason being that what determines the poem's form (its punctuation) is in fact the theological depth. Vivian claims that she understands the meaning of the poem, but what she has actually grasped is, to use Wriglesworth's words, "a linguistic play, a web of poetic surfaces" (215). "It's a metaphysical conceit. It's wit!", she says. Ashford replies, "It is not wit, Miss Bearing. It is truth" (Edson 15). But this is a concept that Vivian cannot grasp. Her exacting and rigid understanding of literature put a distance between her and the work, and does not allow her to go deeper down into the work to fully engage with it and grasp its deeper meaning, to actually *feel* it.

Vivian cannot tolerate sentimentality; she is, precisely speaking, emotionally isolated. She does not even feel comfortable being touched by nurses, because she is not used to kindness (34). She has no family, no friends, and even assumes that her colleagues will delight in the news of her death (32). In another flashback, we see Vivian callously refusing to grant a student a paper extension, considering the death of the student's grandmother to be an obvious pretext: "Do what you will, but the paper is due when it is due" (63). Her perception of wit as keen intelligence and the capacity for

quick understanding compels her to devalue anything that lies outside the boundaries of the brain. This is mostly manifested in her classroom flashbacks in which she purposefully perplexes her students and then harshly criticizes them for being unintelligent (58-60). Vanhoutte asserts that, through her pedagogy, Vivian could fill the gap between thought and feeling. However, she chooses to use teaching as a form of "competitive display" (398), to prove her superiority over students. She praises Donne because his poems have given her a way to demonstrate how good she really is as a scholar (Edson 20). Vivian's attitude towards teaching as an intellectual test rather than an opportunity to break the wall of her emotional isolation reinforces her separation and superiority over her students. The purpose of these flashbacks is to highlight Vivian's preference for scholarly knowledge at the expense of human relations, and her lack of socialization and connection with others. Through being this way she has achieved enormous success as a scholar but has lost her ability to respond to intimacy as a human being.

Vivian is not the only scholar preoccupied with head rather than heart. All the experts in the play are prominent in their fields and are driven by high levels of intelligence. They have piles of degrees and certificates but are cold and uncaring; they are far from humanistic. Their research-led practices have impaired their ability to see bodies as anything other than objects through which they can achieve success. According to Klaver, this situational irony in *W;t* represents a contradictory moment in the history of Western culture, "Two humanist fields dedicated to a tradition of social and individual improvement – medicine and literature – are both guilty of yielding to a perspective that precludes compassionate treatment of human beings" (660). Edson emphasizes this contradiction through the doctors' cold, inhumane, and inconsiderate attitudes. When Dr. Kelekian, for example, delivers the news to Vivian that she has a

fatal illness, he uses technical terms in a 'matter-of-fact' tone without considering the possible effects of this announcement on her: "Please sit down. Miss Bearing, you have advanced metastatic ovarian cancer" (Edson 7). He then explains, in a condescending manner, the side effects of Vivian's aggressive chemotherapy treatment, automatically using the cliché "So far, so good?" (10), totally neglecting the inappropriateness of the literal meaning of good in this context. A few weeks after her short release from hospital, Vivian returns very sick, and is put into isolation. When Kelekian appears in the doorway wearing a mask and gloves, he says, "Good morning Dr. Bearing, Fifth cycle. Full dose. Definite progress. Everything okay… You're doing swell. Isolation is no problem. Couple of days. Think of it as a vacation" (46). Kelekian's research assistant and Vivian's former student, Jason Posner, describes a course on bedside-manners he had at medial school as a "colossal waste of time for researchers" (55), regarding "the part with human beings" an irritating necessity that distracts him from his research: "Everybody's got to go through it. All the great researchers… Like we have to hold hands to discuss creatinine clearance. Just cut the crap, I say" (57). To Jason, his patients, including Vivian, are merely research cases that create new possibilities for understanding cancer. By the end of the play, he cannot even imagine that Vivian has a name; he simply refers to her as "research" (82). Through the medium of her medical characters, Edson not only clearly describes the behavior of doctors but also criticizes their obsession with the pursuit of knowledge, which eventually results in them neglecting their ethical responsibilities towards their patients, who are human beings rather than objects for research. The similarity that Edson establishes between an emotionally isolated brain-oriented literary scholar and inhumane and research-oriented medical practitioners shows that their great respect for knowledge and the impersonality that it entails means that the duality of head and heart is not the defining aspect of their

identities as scholars; rather, the domain of the brain is the only sphere within which they can live, operate, and communicate, and they are flawed as a result.

However, as the play proceeds, over the course of her treatment, Vivian is led to a higher level of insight regarding the meaning of being human that enables her to establish a dynamic interaction between the two opposing aspects of her identity, one as a scholar and one as a human being. Her nurse, Susie Monahan, plays a key part in this emotional transformation. Unlike the doctors who put research before patients, Susie, who according to Vivian, "never was very sharp to begin with" (Edson 69), is the embodiment of compassion and humanity. Kelekian and Jason take Vivian's medical history without really paying attention to her responses (23-24), while Susie not only looks after her but also anticipates her needs. She is the only one who recognizes that Vivian is in a great deal of pain and needs comfort (52). She strokes the weeping scholar and acknowledges her difficult situation: "Vivian. It's all right. I know. It hurts. I know. It's all right. Do you want a tissue? It's all right. *(Silence)* Vivian, would you like a Popsicle?" The stage directions read that Vivian, "*like a child*", says "Yes, please" (65). Susie's kindness helps lower Vivian's defenses; as Green Eads rightly points out, Vivian comes to rely on Susie as if she is her mother (247). Like a frightened child, she pinches the IV tubing so the pump alarm beeps and brings Susie to her room: "I wanted her to come and see me, so I had to create a little emergency", Vivian explains to the audience. Susie affectionately asks her, "What's the trouble, sweetheart?" Vivian again addresses the audience explaining, "Do not think for a minute that anyone calls me 'Sweetheart'. But then… I allowed it" (Edson 64). This nurse-patient exchange of emotions brings about the emotional transformation of the dying scholar and teaches her the true meaning of being human. Vivian's passion for intellectual intricacy prohibited her from embracing any kind of "simple human truth"

(15). She always was "suspicious of simplicity" (61), but now Susie has taught her the art of enjoying "profoundly simple meaning" (14), the art of enjoying "the touch of human kindness" (59):

> That was certainly a maudlin display. Popsicles? 'Sweetheart'? I can't believe my life has become so… corny. But it can't be helped… Now is not the time for verbal swordplay, for unlikely flights of imagination, and wildly shining perspectives, for metaphysical conceit, for wit. And nothing would be worse than a detailed scholarly analysis. Erudition. Interpretation. Complication. *(Slowly)* Now is a time for simplicity. Now is a time for, dare I say it, kindness. (69)

With the help of Susie and as a result of her struggle with cancer and her suffering, Vivian finally finds her compassionate side. She realizes that as a human being she needs to connect meaningfully with others and be exposed to human feelings. Susie helps her to find the dimension she has been missing in her life: the simple truth of human kindness and interaction. Now she is ready to let go of complexity and embrace simplicity. This desire for simplicity is manifested in the decision Vivian comes to in case her heart stops. At first, she decides to let the doctors resuscitate her so they can continue their research on her: "I always want to know more things. I'm a scholar" (68), she says. But then she changes her mind; she simply does not want to "complicate the matter" anymore (68). She therefore asks Susie to request a 'do not resuscitate' order.

Vivian's entrance into the world of simplicity as a scholar, however, completes towards the end of the play, when Dr. Ashford comes to visit her a few minutes before her death. She offers to read some of Donne's poetry, but sensing Vivian's strong reluctance, she reads instead from a children's book, *The Runaway Bunny*. Using eighty years of experience as a scholar and literary critic, Ashford analyzes this story to get to its deeper meaning. Rimmon-Kenan explains that here, Edson tries to "suggest an affinity between the simple children's story and the poetry of Donne, which hitherto has seemed to be at the opposite pole of sophistication" (352). *The Runaway Bunny* is in fact a simplified version of Donne's sonnet "If Poisonous Minerals", to which Vivian

refers in a recalled lecture early in the play. In the children's story, the little bunny wants to run away from her mother by taking different forms (a fish, a flower, a rock…), but whatever disguises he assumes, his mother finds him (Edson 80). In Donne's poem also, the speaker hides under a rock because he is afraid of God's knowledge of his sins. Rather than trusting God's mercy, he decides to hide (50). Juxtaposing the two versions of the same story, one simplified and one sophisticated, and showing Vivian's acceptance of the former and rejection of the latter, the play reveals that she has finally learned the truth: that literature is not there only to display sophistication or to humiliate others with; rather, it should be used to equip people for life, to help them adapt to situations, as Shepherd-Barr explains (171). Vivian eventually learns what her professor was trying to teach her in the flashback tutorial: analyzing literature without the ability to perceive its deeper meaning is wrong. A simple text like *The Runaway Bunny* and complex texts with so much wordplay like Donne's poems can convey the same simple meaning. Here, Vivian has made a gradual transformation from an intelligent scholar armed with linguistic expertise to an illuminated scholar equipped with wit, the ability to perceive and understand depth and meaning; she has turned into a scholar with both a big brain and a big heart. She is now home to a paradoxical complementarity.

3.2.2.2 Failure + Success = Redemption

W;t seems to be advocating the pervasive idea about cancer according to which it is a source of psychologically, as well as physically, malign processes. The play provides a detailed description of the agonies and pains Vivian has to endure as a result of both the cancer and the treatment. Nevertheless, this perception changes throughout

the play; the audience gradually realizes that despite all the anxiety, pain, and negativity inherent in cancer, it can become a source of ultimate peace, recognition, and eventually redemption. It requires a powerful force for Vivian to break herself out of the hard walls of emotional segregation that she has built around herself: cancer proves to be that force. It is through cancer that she eventually learns "how poems feel" (Edson 16). This wry observation is the one that, as Vanhoutte explains, "casts her suffering as a form of Aristotelian reversal, a 'change from one state of things within the play to its opposite,' leading to enlightenment" (399).

Early in the play, Vivian says that "One thing that can be said for an eight-month course of cancer treatment" is that "it is highly educational" (Edson 31). The pain and the harshness of the cancer emerge as new understanding and recognition, reminding Vivian that she needs "the touch of human kindness" (59). It is through cancer and its harsh treatment that she finally breaks the walls of her emotional isolation and learns how to interact with her other human fellows. By yearning for kindness, Vivian makes friends with the unliterary Susie, who comforts her, listens to her, and eases her pain and in doing so learns how to be human.

However, what is crucial to understanding *W;t* is that, according to Edson, Vivian's suffering is a vehicle of God's mercy; it is in fact a means to correction and eventually redemption and indeed the play's final scene depicts a redemptive moment. While the code team is mistakenly trying to revive Vivian due to Jason's calling a code on a no-code, she slowly rises from her bed, takes off her cap and gown, and walks towards a little light that is coming from the edge of the stage. In this state of "volitional self-emptying, or kenosis" (Wriglesworth 218), Vivian is seen "naked, and beautiful, reaching for the light" (Edson 85). This last scene is in fact the actualization of the "immortality" that, according to Jason, is inherent in cancer (56). If the doctors failed to

save Vivian medically, cancer saved her spiritually. As Edson explains, "Grace… is the opportunity to experience God in spite of yourself" (Martini 22) and cancer gives Vivian this opportunity. It shows her the need to change and to be contrite, and eventually opens the way for spiritual redemption. In Edson's opinion, although the doctors register Vivian's death as failure, it is actually a success.

This meaning of the play is made more evident in Ashford's reading of *The Runaway Bunny*. She sees the story as an "allegory of the soul. No matter where it hides, God will find it" (Edson 80). Although "the smartest guys in the world, with the best labs" (57) fail to explain the nature of cancer, Edson simply defines it, as Vanhoutte beautifully puts it, "as God's method for finding the runaway souls of overweening intellectuals" (404). In this context, the scientific and medical framework within which Edson places her play takes a positive turn and becomes a source of redemption and salvation for her protagonist. *W;t*'s depiction of cancer as the generator of both failure and success suggests that the reconciliation of opposites forms its ultimate identity.

3.2.2.3 To Teach vs. to Be Taught

Vivian is a source of another reconciliation of oppositions in the play: a teacher who is now being taught. She who used to conduct seminars has become the object of study. Early in the play, Vivian's acceptance of being a significant contribution to specialized knowledge herself turns her body into an object for medical experiment. She is an object of research that has been analyzed, scrutinized, and anatomized to help expand the boundaries of human knowledge. This objectification of Vivian is clearly depicted in the scene in which Jason is examining her pelvis, with her feet in stirrups and knees spread apart. While groping her intimate areas, Jason talks about his

admiration for Vivian's teaching and her classes. This scene depicts Vivian's transformation from an observer, a subject, to an object of study on a former student's examining table. For Jason, Vivian is only an object among other objects, to be used and studied for the sake of research. The irony of the fact that what the doctors are doing to her now is very similar to what she has been doing all her life, dissecting Donne's poems down to their punctuation, is made evident to her in the Grand Round. As she observes, "Full of subservience, hierarchy, gratuitous displays, sublimated rivalries – I feel right at home. It is just like a graduate seminar. With one important difference: in Grand Rounds, they read me like a book. Once I did the teaching, now I am taught" (Edson 36). In other words, Vivian, who as a scholar has always been at the observing end of the microscope, is now the object being scrutinized and analyzed under it. She is an observer being observed, a teacher being taught, a subject being objectified.

As the above discussion has shown, Edson's play is full of oppositions that eventually come together and form unified entities. A scholar torn between the allure of academic endeavor and the need to feel eventually becomes both and achieves redemption; a fatal medical condition turns into both a source of negativity and pain and positivity and redemption; and a teacher who has always been the subject of research becomes the object of research in the eyes of medical practitioners. All these oppositions eventually form themselves into unifications, a metaphorical enactment of post-quantum reality, in which electrons' existence is defined as the union of oppositions.

3.2.3 Does Distance Matter?

At the heart of *W;t* there is a complex network of similarities that creates connections between two temporally and spatially distanced worlds, one in England in the early seventeenth century (Donne's) and one in America, in the closing years of the twentieth century (Vivian's). This network of similarities is formed within the framework of the metaphysical concept of a conceit, that is, a "likeness in things unlike whose ingenuity is more striking than its justness, or, at least, is more immediately striking" (H. Gardner 19). *W;t*'s central conceit establishes similarities between a contemporary American female literary scholar and a seventeenth-century British male poet who are very much unlike one another: Donne is a poet whose poetry is known to be "a direct sensuous apprehension of thought, or a recreation of thought into feeling" (Eliot 669), while Vivian is a scholar trapped within the boundaries of form and surface. However, the constant comparisons that Edson makes between them reinforce their similarities and therefore their connections, regardless of the vast temporal, spatial and personality differences between them. In doing so, *W;t* itself can be read as a metaphorical representation of the quantum theory of entanglement, another conceit that is created in the play.

The first similarity between the distanced worlds of the play's literary figures is established when Edson clarifies to her audience why Vivian chose Donne as the focus of her scholarly career. Donne's Holy Sonnets are characterized by witty wordplay and a complex vocabulary. In the play also, what is deeply moving about Vivian is her love of language. In a flashback to her childhood, Vivian explains how this love came to the fore. It is Vivian's fifth birthday and she is grappling with one of Beatrix Potter's books. Trying to sound out the word 'soporific', she asks her father what the word means. He explains, "Makes you sleepy. Causing sleep" (Edson 42). Vivian notices that the bunnies in the illustrations of the book are asleep which comes to her as an

epiphany: “The little bunnies in the picture are asleep! They’re sleeping! Like you said, because *of soporific*!” The now-fully-grown-up Vivian then explains to the audience, “The illustration bore out the meaning of the word, just as he had explained it at the time, it seemed like magic”. Here, the very first signs of Vivian’s love for complex words are revealed. She continues, “So imagine the effect that the words of John Donne first had on me: ratiocination, concatenation, coruscation, tergiversation” (43). Moreover, apart from forming a connection between Donne and Vivian on the grounds of their great interest in sophisticated words, Edson also suggests that, similar to Donne who used “a complex and difficult language… to be witty and clever” (Carter 25), Vivian also uses her wit to show how clever she is. She revels in the “subtleties of seventeenth-century vocabulary, versification, and theological, historical, geographical, political, and mythological allusion, Donne’s wit is… a way to see how good you really are. After twenty years, I can say with confidence, no one is quite as good as I” (Edson 20).

The connection between Vivian and Donne is also established in the play through the spiritual journey that Vivian undergoes and the poetry that she studies. Central to the play is one of the most famous of Donne’s Holy Sonnets, “Death, Be Not Proud”. This sonnet first appears in the previously discussed flashback with the twenty-two-year-old Vivian and Ashford. Having indulged herself in a series of literary analyses and scholarly endeavors, Ashford states that the juxtaposition between the two versions of the sonnet depicts two totally different views of the relation between life and death. The correct version of the poem, according to her, bridges the gap between life and death:

> The sonnet begins with a valiant struggle with death, calling on all the forces of intellect and drama to vanquish the enemy. But it is ultimately about overcoming the insuperable barriers separating life, death, and eternal life… Nothing but a breath – a comma – separates life from life everlasting. It’s very simple really.

> With the original punctuation restored, death is no longer something to act out on a stage, with exclamation points. It's a comma, a pause… Life, death. Soul, God. Past, present. Not insuperable barriers, not semicolons, just a comma. (14)

In this interpretation of the poem, death is not viewed as the opposite of life; instead, it is represented as a pause between life and life everlasting. "Insuperable barriers", as Rimmon-Kenan explains, "are replaced by a threshold – connecting, bridging, even as it separates. The comma emerges as an expression, on the level of punctuation, of a creation of rapprochement between seeming dissimilarities" (350). The final scene of the play offers a theatrical analogue of this sonnet. Vivian's journey ends where it began. Her death is indeed a smooth transition, highlighting the similarity between two stages that, according to the doctors who are reviving her, are radically contrasted. Shepherd-Barr explains, "While [Vivian's] soul serenely detaches itself, Jason and the code team have been trying to enforce a semicolon – or, worse still, an exclamation point! – where there should be only a comma" (170). When Vivian reaches for the light, the theatre lights dim and the play ends. Edson wants the audience to believe that Vivian's death has, in fact, been a pause, "a transition to a state of quasi-transfiguration" (Rimmon-Kennan 350). The important role that punctuation plays in changing the meaning of Donne's poem is further emphasized in the title of the play where instead of the letter 'i' Edson decides to use a semicolon.

Another way by which Edson links Vivian to Donne is by alluding to another sonnet by him, "This is my play's last scene" (Edson 52). This sonnet is particularly important when compared to the final stage of Vivian's illness: "I have always particularly liked the poem", she says, "In the abstract. Now I find the image of 'my minute's last point' a little too, shall we say, pointed" (52-53). At another point in the play, she once again refers to this poem when she is being injected with aggressive painkillers: "I apologize in advance for what this palliative treatment modality does to

the dramatic coherence of my play's last scene. It can't be helped. They have to do something. I'm in terrible pain" (70).

Edson's allusions to Donne and to his poetry, as well as her exploration of Vivian's life within this context, forms a strong connection between two people and two worlds that not only are thousands of miles and billions of hours apart, but who also seemed to be so different from each other. This connection between two distanced realms works in the same way as the connection that two particles make once they connect, regardless of how far apart from each other they are, suggesting how deeply rooted the play is in an understanding of the concepts of contemporary science.

Edson's appeal to literary criticism and to Donne's poetry to discuss the grand issues of human existence, namely life and death, and the redemptive ending that Vivian is granted thanks to the medical and scientific context within which her transformation is made possible, bridges the vast distance between the two opposite realms, literature and medicine, in the fashion of the metaphysical conceit: what makes us all the same is that, regardless of being a doctor, a poet, or a literary scholar, we are all human beings, and must live and die as human beings. Vivian's realization that scholarly knowledge should not confine our humanity teaches us, as academics, doctors, and people, to question and challenge our own scholarly lives to eventually understand and 'feel' Edson's message: that our lives should be formed and defined within the context of other lives rather than books, journal papers, and articles. Because it is through 'the touch of human kindness' that we can make death another part of our lives, only a comma away.

W;t is a science play that can be placed in the category of 'science as supporting character' due to the peripheral role that medicine in general and chemotherapy in particular – as a medical treatment – have in the play. Edson uses medicine and its

practitioners as a necessary context to explore and discuss a nonscientific issue that has been raised by science: the redemptive power of cancer and the dehumanization of patients by doctors. However, as the above discussion has revealed, despite the minimal role of science in *W;t*, the play's duality of contexts (science and literature) enables us to discuss it within a third context, that of new physics: through the device of memory, Edson creates onstage a jumble of different past and present slices of the life of her protagonist and in doing so reveals her preference for the Einsteinian perception of time over Newtonian temporal/spatial absolutism; time is nonlinear in the play, meaning the narrative takes quantum leaps from one time frame to another; the depiction of the protagonist as the unification of contradictions enacts the same reconciliation of opposites that characterizes subatomic elements; and the bond of similarity that Edson creates between the two literary geniuses of her play enables them to instantly travel continents and centuries to connect with each other, through the same spooky action at a distance as found in electrons in the quantum universe. The following section will explore the intersection between the perception of reality as presented by new physics and contemporary science plays within the context of another first-category science play, *An Experiment with an Air Pump*.

3.3 Shelagh Stephenson's *An Experiment with an Air Pump*: The Dialectical Ethics of Scientific Research

An Experiment with an Air Pump is an in-depth exploration of the dichotomy that science has always presented: scientific ethos at the expense of moral ethics or moral ethics at the expense of the scientific ethos? Stephenson dramatizes a string of ideologies that respond to this dichotomy and aggregates them in dialogue. In the

process, a set of opposite concepts emerges that form themselves into pairs, the two halves of which simultaneously seek and avoid resolution. However, Stephenson does not depict these oppositions as separate entities; rather, she demonstrates how, despite their differences, their fuzzy edges collide and blur to eventually create oppositional yet unified entities.

An Experiment's oppositional pairs are personified in the characters and are dramatized within two different narrative contexts set in two different time periods, 1799 and 1999, the turns of two centuries that are the bookends of modern science: one signaling the birth of the Industrial Age and the scientific advancements of the Enlightenment, and the other, the age of biochemistry, in which drawing the human DNA map is no longer a dream. The play takes place in a house in Newcastle-upon-Tyne in northern England, where in 1799 a renowned scientist, Joseph Fenwick, lives with his wife, Susanna, his twin daughters, Harriet and Maria, and two visiting physicians, Thomas Armstrong and Peter Mark Roget, who in 1852 published the first thesaurus of English words. The same house belongs in 1999 to a middle-aged couple, Ellen, a genetic scientist, and her husband, Tom, a redundant English lecturer. The contemporary narrative contains two more characters: Phil, an anti-science building surveyor who has come over to survey the couple's building, as they are planning to sell it due to financial problems; and Kate, Ellen's best friend, who has a lucrative job offer for her with a pharmaceutical company which has invested huge sums into fetal genetics research. At the heart of both narratives there is a scientific ethical crisis. In 1799, Armstrong tries to seduce Isobel Birdie, a vulnerable serving girl with a spinal deformity, to get to see her naked only "to examine her beautiful back in all its delicious, twisted glory" (Stephenson 220). When Isobel learns Armstrong's true intentions, she kills herself in despair. Armstrong finds her hanging from a rope, still

alive. He cuts the rope and gets her down, then finishes her off by smothering her to have her body for research. In 1999, Ellen's job offer involves experimenting on pre-embryos with the ultimate aim of mapping the human genome. The scientists in two time periods two centuries apart make the case that moral concerns have to be discarded for the sake of scientific advancement, suggesting that not so much has changed in the realm of science through the years. This perception of science brings about the ethical consequences and concerns that form the main tension in both narratives.

But Stephenson's play is not only about morality. It is also about the future that scientific progress has to offer. Zehelein argues that Stephenson "toys with and correlates with the present and the past, only to gear her dramatic action towards the future [to] ultimately comment on… human and scientific progress" (148). The theme of progress echoes throughout both acts, beginning in Scene 1, when Fenwick hopes to enter the new century on a happy and confident note due to the bright future that scientific advancements have promised. His New Year Eve's lecture starts with the following sentence: "We stand on the threshold of a new century, we stand at the gate of a New Jerusalem" (Stephenson 153), then goes on to highlight progress and futurity, something that is "worthy of the past and fired by visions of the future" (144). Added to this, in 1999, what worries Tom is the future. He is concerned that Ellen's work might cause dangerous aspirations towards the perfectibility of man by giving birth to a market-motivated medical service, which would use genetic techniques to publicize eugenic control (188).

Similar to *W;t*, *An Experiment* reduces the role of science in the play to a peripheral position and places its central focus on the ethical aspects of scientific endeavor. By having scientists among their cast of characters, Edson and Stephenson provide a description of and commentary on the behavior of the scientists and their

perception of science as a discipline at the altar of which humanity and ethics are to be sacrificed. These science play practitioners create a world whose inhabitants are either involved in science or have been affected by its consequences. Stephenson even takes one step further and visualizes the future that this perception of scientific ethics envisions. Due to the real sciences of anatomy and biology not being the main focus of attention in *An Experiment*, Stephenson also refuses to explain them accurately and precisely or to use them metaphorically, and similar to her fellow science play practitioner assigns science a supporting role.

In *An Experiment*, the concepts of scientific ethics and the futurity of scientific progress are explored within the framework of Joseph Wright's painting "An Experiment on a Bird in an Air Pump" (1768). The play opens with a slowly revolving tableau involving the whole cast except for Ellen, suggesting the painting. By positioning themselves as the figures in the painting, the actors reveal to the audience the characters they are playing. Four large projections of Wright's painting are placed above the audience. Ellen, looking up at them, comments on the painting and explains how, as a child, it "described the world to her" (139) and inspired her to want to be God. Through Ellen's analysis, the interpretive potential of the play emerges:

> I've loved this painting since I was thirteen years old. I've loved it because it has a scientist at the heart of it, a scientist where you usually find God… This painting described the world to me. The two small girls on the right are terrified he's going to kill their pet dove. The young scientist on the left is captivated, fascinated, his watch primed, he doesn't care whether the dove dies or not. For him, what matters is the process of experiment and the intoxication of discovery. The two young lovers next to him don't give a damn about any of it… But the elderly man in the chair is worried about what it all means. He's worried about the ethics of dabbling with life and death. (139-40)

The painting has been regarded as an accurate and realistic representation of a scientific experiment, commenting on progress and rejoicing in British

industrialization.[35] However, by looking at the painting, it is immediately noticeable that it is not so much the experiment itself that interests Wright – only four of the ten figures are actually watching it – rather, it is the attitudes and the reactions that the characters in the painting exhibit towards the experiment. The same happens in Stephenson's play. She uses science only as a necessary context within which to discuss the *ethicality* of scientific endeavor. By dramatizing a painting with a scientist at the heart of it and different personas each reacting differently to the scientific experiment, Stephenson inserts into her play a multiplicity of voices and views regarding the idea of scientific morality, and gradually broadens it out to present model of the universe. No matter how we interpret morality within the context of scientific research, the model suggests, the conflict between the two has always been and will always be at the heart of human life. As Zehelein explains, "Change comes with circumstances in the name of progress, yet the core conflicts remain for us to face" (162).

As the figures in the painting spring into being the similarities between Wright's personas and Stephenson's characters are gradually established. Fenwick is the scientist that Ellen superimposes on the central figure of the painting, the experimenter. He is looking straight out of the painting, at the spectator, staring at the threshold of the future with his mouth half-open in awe and excitement. His right hand is positioned above the glass globe and his left hand is held out towards the spectators in an inviting gesture, as if challenging them to decide whether he should continue the pumping and so kill the dove, or whether he should replace the air and so save it (Appendix 1, Fig. 1). Armstrong is sitting on the experimenter's right side, timing the dove's last breath, fascinated only by the experiment. Maria and Harriet are the two young girls on the right, one worriedly watching the experiment, the other hiding her face in her hands.

[35] See Burke, Joseph. *The Iconography of the Enlightenment in English Art*. Sydney: Sydney UP, 1970, 14-17.

The young lady standing to the left of the experimenter is Susannah, focused exclusively on the young man, totally indifferent to the experiment. The man standing behind the young girls, trying to calm them down, is Roget. The dove in the glass globe, highlighted on one side and in shadow on the other, is Isobel. And the old man on the armchair seems to be a disillusioned version of the experimenter, whose optimism is muted at the end of the play due to Isobel's death. Like the old man in the armchair, he is lost in contemplation worrying about the ethicality of science and the future it is supposed to bring about.[36]

But Stephenson's depiction of the futurity and ethicality of scientific progress is not entirely negative; rather, she prefers to take a neutral standpoint by presenting the late twentieth-century versions of the experimenter beginning the new century with hope in their hearts. Stephenson's parallel depiction of hope and despair in the very final image of the play suggests that what she actually wants to show is the unknowability and indeterminacy that lies at the heart of scientific progress and scientific ethics. In fact, they are open to dispute and, similar to Wright's bird, can be simultaneously brightened and darkened by the lights and shadows that people decide to present them in. Despite the fact that in Stephenson's play science does not play the leading role, the way she manipulates time, narrative, characters, and the ending of the play make it a perfect case to explore the implications of new physics.

3.3.1 Time-Unbound Ethics

Unlike *W;t*, which appeals to memory to challenge Newtonian temporal

[36] There is not an exact one-to-one correspondance between the characters in the play and the personas in the painting. The couple in love could be interpreted as Amrstrong and Isobel, or Maria and her fiancé Edward. The young girls are too young to be Harriet and Maria, and they are not twins.

absolutism, *An Experiment* follows the same pattern of first-cyclical-then-merged time fluctuations as used in *Arcadia*. Similar to Stoppard's play, the time alteration also happens in the same place. In *An Experiment*, the actions of the play take place in the same grand English manor, located in Newcastle. In the first two scenes of Act I and scenes 1, 3, and 4 of Act II, past and present are featured separately. However, during the rest of the play the characters from the two time periods have the option of standing onstage together, though they never interact. The formal separation of timelines collapses in these scenes as the characters from one time period enter while the characters from the other time period remain on the stage, frozen in time. In other words, each of the groups is in its own time and only shares the space of the stage with the other. The juxtaposition and overlap of the two time periods is essential to the thematic operation of *An Experiment*. By the simultaneous presentation of two groups of scientists dealing with the same ethical issues concerning the deployment of their knowledge, regardless of the two hundred years' time difference between them, Stephenson underlines the durability of the ethical struggle that science presents. This 'echoing' of content is further emphasized by the fact that the actors who play Susanna and Fenwick double as Ellen and Tom, while the actors who play Phil and Kate double as Armstrong and Harriet. They embody the play's temporal duality but simultaneously act as an element of continuity. Stephenson's rejection of Newtonian temporal absolutism enables this actor/content echo effect to do its job of reinforcing the connection that she intends to create between the past and the present on the theme of scientific ethics. Similar to *W;t*, the nonlinear, non-chronological manipulation of time results in an episodic narrative structure that can be read as a figurative representation of quantum mechanics, as the play takes quantum leaps from one time orbit to another.

3.3.2 No Linear Time, No Linear Narrative

As mentioned before, *An Experiment* contains two narratives lines, one historical and one contemporary. Each narrative, when considered individually within the scope of its own time period, develops in a perfectly linear fashion. However, when observed within the framework of the play, the narratives unfold episodically due to the play's constant shuttling between the two periods. *An Experiment* begins in the past with the historical narrative smoothly and gradually unfolding on stage. The audience sees the late seventeenth-century characters discussing scientific and domestic issues. This narrative, however, suddenly takes a nonlinear turn when confronted with a fragment of the contemporary narrative that has taken control of the stage and moved the play's clock forward. This interruption of the linear flow of the historical and contemporary narratives by the constant emergence of each other's fragments continues throughout the play, giving the narratives an episodic appearance. A contemporary fragment appears, the historical narrative disappears, a historical fragment appears, and the contemporary narrative disappears, and so on. This constant appearance and disappearance of narratives in the play brings to mind the discontinuous quantum transition of electrons from one state to another around the nucleus inside an atom.

Moreover, each narrative contains fragments of the other narrative, thereby contributing to its unfolding process. For example, the contemporary narrative involves the discovery of a box of bones in the basement and the characters' attempt to find out to whom they belonged and what happened. In each visit to the past, more details about the owner of the bones, and his/her destiny are revealed to the audience, until it gradually transpires that they belonged to Isobel. The contemporary narrative also includes pieces of information about the past inhabitants of the house that help fill the

gaps in the historical narrative. For example, through Tom and Ellen's conversations we learn about Fenwick's scientific and social achievements (Stephenson 164). This collaboration between the 1799 and 1999 narratives to release each other's fragments and the episodic fashion in which they unfold turn the play into a 'test-your-intelligence game' for the audience, in which it has to identify the fragments, categorize them, put them in order, and then construct a linear narrative out of them. The audience's intelligence is further challenged when, in the course of the play, it is introduced to a set of complementary oppositional pairs that Stephenson places her characters in.

3.3.3 Oppositional/Connected Pairs: Local and Nonlocal

As explained before, in Edson's play, the reconciliation of opposites either occurred within a single body, that of the protagonist or with relation to her. In *An Experiment*, however, the oppositional pairs emerge through the clashes between ideologies and are represented by different characters: moral ethics and scientific ethos, idealism and pragmatism, science and literature, head and heart. However, these pairs are not merely oppositional; rather, as Barnett argues, they are "dialectical, which means that each half informs and enhances the other" (216). They are, in other words, two oppositions that play a complementary role and display a dialectical harmonization. The connection between these oppositions is not limited by their temporal differences. They sometimes form themselves into pairs within the boundaries of the same time period, or decide to travel for two hundred years, back or forward in time, to connect with their appropriate halves. The personification of concepts in the figures of the characters introduces a complex network of human connections into the play, which makes this interplay of opposites even more complex and consequential. The

paradoxical complementarity that these human pairs contain and their occasional travel across vast temporal distances to connect with each other is a dramatic enactment of the wave-particle duality that lies at the heart of subatomic entities and the network of nonlocal connections they create in the course of their entanglement.

Depending on their distinctions and differences, the characters can be paired into two different categories: oppositional pairs and counter-ego pairs. The characters in the first category belong to the same temporal dimension, whereas the characters in the second category have to travel through time to make connections. The following two sections provide a thorough description of these conflicting relationships.

3.3.3.1 Local Oppositional Pairs

Fenwick is an empirical idealist who rejoices in the future of mankind and the potential of science to change the world for the better (Stephenson 182). He believes that "the relentless, irresistible advance of science and the consequent wider dissemination of knowledge" (179) will bring infinite well-being, social equality, and eventually democracy to human kind, so that:

> By the end of the nineteenth century every man or woman in the street will understand more than we can ever dream of. Electricity, the stars, the composition of the blood, complexities beyond our imagination, will be as easily understood as the alphabet. Magic and superstition won't come into it. And it stands to reason, any citizen with the facts at his disposal could not tolerate a monarchical system unless he was mentally impaired or willfully resistant to reality. (180)

Fenwick "positions science, knowledge, and democracy on one side of his equation and superstition, ignorance, and monarchy on the other" (Barnett 210). His extreme faith and pride in the Enlightenment belief that the pursuit of knowledge is an unmitigated good has blinded him to the negative ramifications that scientific research might

present. In his opinion, morality and affection are at the center of scientific research, because science cannot possess a cold heart and thus cannot be immoral (Stephenson 182). To him, the age of Enlightenment is the fulfillment of man's great hope of science bringing about social improvement, and it is humane and progressive and cannot be otherwise (144).

Fenwick's utopian dream is juxtaposed with Armstrong's material pragmatism. He is a ruthless scientist anxious to examine deformed bodies and even confesses to waiting for "potential cadavers" to die so that he can dissect them: "We've got our eyes on an undersized fellow, about three foot tall. He's not at all well. He'll not see out the winter" (206). For Armstrong, stealing dead bodies and slicing them open is the path towards enlightenment and progress: "Digging up corpses is necessary if we are to totter out of the Dark Ages" (206). Unlike Fenwick, he does not have any moral qualms because to him: "Discovery is neutral. Ethics should be left to philosophers and priests" (206). He is a totally corrupt and unscrupulous anatomist who does not shy away from seducing a vulnerable hunchback servant and then murdering her for the sole purpose of analyzing her deformed body. The only thing he cares about is the advancement and progress of science, regardless of the means used or the potential consequences. Fenwick, without knowing about Armstrong's vicious deeds, detests him just because he believes that he is cold of heart while science requires a warm heart (184). Here, Fenwick's radical idealism and Armstrong's extreme material pragmatism are presented as the two poles on the spectrum of scientific morality.

Among the eighteenth-century women, Susannah is given the role of temperamental female opposite to Fenwick. While her husband is "sitting at his desk, writing calmly", she sits at a small card table "endlessly playing patience, drinking brandy, and growing steadily more intoxicated" (141). Unlike Fenwick, "an exemplary

man, a great scientist… whose learning is universally admired" (209-10), she is ignorant and anti-science, and does not care about intellectual issues, and with her little education in literature, believes that "One Shakespeare is worth ten Isaac Newtons" (156). The opposition between Susannah and Fenwick is displayed through the way they treat their daughter, Harriet. She aspires to be "a physician, like papa" and has succeeded in inventing a hat that puffs smoke. Susannah, however, is frightened by her aspirations: "Did I hear her correctly? … Has she taken leave of her senses?" She cannot understand the point of her daughter's invention: "But when would you wear such a thing, dear?" (199) She instead encourages Harriet to write a play, as to her this is a more appropriate diversion for a woman. Susannah's preference for literature is juxtaposed with Fenwick's prioritization of science. Unlike his wife, Fenwick finds Harriet's play "dreadful" but is impressed "beyond words" by her invention, and tells Susannah to "shut up" when she describes it as "singularly useless" (199). He even forces his daughters to sit through his experiments and the scientific talks by his visiting speakers, just because to him they are illuminating (154).

The opposition between Susannah and Fenwick is also illustrated through another dichotomy: head vs. heart. Throughout the play, the audience realizes how unhappy Susannah is with her life: "All life's a bitter disappointment, Mr. Armstrong. Take it from me" (143). The reason for her dissatisfaction and disappointment is her husband's indifference to and lack of affection for her: "You have feelings for every passing stray but none whatsoever for me" (215). In a climactic monologue that also represents the stereotypical female role model of the time as a passive thing with no voice of her own, she explains:

> I was a passive thing, waiting to be filled up with love and ooze it out in return. That is what young women do, Joseph, they wait to be loved, they wait for a man to bestow his mysterious gift upon them. I loved you because you loved me. That was my criterion. What else did I have to go on? What else did I know? You

caused this love in me! You planted it in me and then you abandoned it! (215)

Stephenson presents Susannah as the ignorant emotional counterpart to her scientist husband whose extreme pride in his radical ideas forces him to be overly logical. His excessive logic is made evident when he fails to see (or willingly decides not to see) what Roget sees in people's eagerness to have monarchy: "It seems to be a condition of existence to resist an idea of reality when it threatens a tradition of mystery… People like the monarchy because it's got nothing to do with reality" (180). Fenwick does not even want to be associated with affections. When Susannah (rightly) points out his "pure affection" for the mob, he gets angry because, as Harriet says, "You accused him of affectation and you know how he loathes that" (149). Similar to her mother, Maria also feeds on romance only and is indifferent to intellectual questions; in her monologues in the play, she reads romantic letters that her fiancé, Edward, writes to her from India.

The women in 1999, on the other hand, have not only entered the male-dominated realm of science, but have succeeded in it. They are no longer passive onlookers to the processes that are changing their lives. Here, women and men have swapped roles. As an English lecturer, Tom's life is inextricably intertwined with art and poetry. He is a redundant professor with little chance of getting another job (184). Unlike Tom, Ellen is a very successful molecular biologist who is quite independent from her husband. Now that Tom has lost his job, he has to rely on his wife and her income. However, he does not approve of Kate's job offer because it involves experimenting on pre-embryos, which to him is immoral – even though it would enable them to keep their house (186). When Ellen insists that she does not have a problem working with pre-embryos and that it does not necessarily make her "some sort of murderess", Tom asks her, "how many times have you been pregnant?" (187); when she

answers “Five” he corrects her, “Six”, adding that “from the very first moment [you felt] ecstatic” and that, “On at least two occasions, when it was no more than what you now refer to as ‘a cluster of cells’ you called it pregnancy. You knew it was a potential person” (187). Here, the husband is presented as more maternal than the wife. Later in the play, Tom asks Ellen the same question about Isobel’s bones. He refers to them as “a dead body” (184), with which Ellen disagrees:

> ELLEN. It’s not a dead body.
> TOM. That’s what it started out as –
> ELLEN. A long time ago.

But he insists: “So what’s the difference? At what stage does it stop being disturbing and start being archaeology?” (185) According to Tom, both the pre-embryos and the bones found in the basement are human beings, whereas to Ellen they are only scientific objects.

Tom’s total opposite, however, is Kate, whom he accuses of being unscrupulous and ambitious: “You’d dissect your own mother if you thought it might give you the answer to something” (223) – to which she replies in the affirmative. Kate’s complete lack of sympathy becomes more evident when she begins to explain their work to Phil: “We’ll be able to eradicate all sorts of things. Schizophrenia, manic depression” (173). But Phil, who takes a strong stand against these technologies, cuts her off and describes his schizophrenic Uncle Stan who was “magic. He built us a tree house covered in shells and bits of coloured glass”. He then asks Kate if their research means there will be no more Uncle Stans, to which she meanly responds: “How is your Uncle Stan these days?” When Phil answers that he “killed himself”, she maliciously replies, “I rest my case” (173).

Stephenson seems to be leading her audience to a world defined by either/or. A place where there are only absolute blacks and absolute whites. However, the deeper

down we go into the play, we realize that they in fact complement each other. This will be discussed further at the end of this section.

3.3.3.2 Nonlocal Counter-Ego Pairs

Most of the characters in *An Experiment* have a counter ego, reinforced by the fact that the same actors play both the characters in one time period and their opposites in the other time period. For example, the role of Armstrong, a totally corrupt and unscrupulous anatomist who has "never had a moral qualm in his life" because "it would be death to science" (207), is played by the same actor who plays the present-day Phil, an uneducated workman who believes in 'flying saucers' and the spontaneous combustion of human beings. To him, scientists have closed minds. They are rational people who hide themselves behind objective evidence and try to clothe their work in mystery: "You see, that's why people don't trust scientists. They're always up to something" (171). The actresses who play Susanna and Harriet also play their present-day counter egos, Ellen and Kate. The ignorant Susanna and the moderately talented Harriet of 1799 have morphed into the extremely intelligent Ellen and Kate of 1999, two scientists who are trying to map the human genome system in order to ultimately change the world (173). Thus, the passive, ignorant wife and daughter of the past have become the scientists of the present working at the cutting edge of technology. The same actor also plays both Fenwick and Tom, meaning that an idealist progressive physician with a blind faith in science is morphed into a modern-day English lecturer who is pessimistic about the idea that scientific advancements can ultimately bring a better life for the human race.

These characters and their counter egos switch from one extreme to another,

with no comforting middle ground, and the fact that they are played by the same actors reinforces the point that they are complementary pairs. They are two incompatible properties, located in two different time periods with two hundred years' difference, who have become united within a single body, a body whose existence is defined by the union of opposites. Through the medium of the actors' bodies, Stephenson instantly gets two characters entangled across vast temporal distances.

However, the connections that Stephenson makes among her distanced characters are not only based on their distinctions and differences. The historical and contemporary characters are also paired and therefore linked with each other according to their common characteristics. The following section clarifies the point further.

3.3.3.3 Nonlocal Connected Pairs

In *An Experiment*, the past characters are presented as going through a two hundred-year-long process of evolution into the present-day characters. Fenwick, Susannah, and Armstrong's evolutions into Ellen, Tom, and Kate are accompanied by a radical shift in gender roles and implicit personality and ideological changes.

At the beginning, it seems that Ellen and Kate are similar because Ellen's research on pre-embryos also casts her in a wicked light. However, we gradually realize that this is not the case. At one point in the play, Ellen admits to Phil that she is "having an ethical crisis" (171), which causes her to seem less complicit. Some of her responses to Tom also prove that she is not as amoral as Kate is: when Tom asks, for example, "Where's it all leading? … Can you imagine what insurance companies will do with that information? Mortgage companies? Health insurers?", she responds, "Oh for God's sake, Tom, do you think I don't worry about these things?" (188) Similarly, Ellen

herself also believes that she and Kate are different: “The fact that you’ve never had a moral qualm in your life doesn’t mean you have superior reasoning power, it just means you have a limited imagination” (171). She eventually decides to accept the offer because “You can’t not pursue something, you can’t say the road might have complications so I won’t go down it. Once you know something, you can’t unknow it” (224), she explains. Barnett argues that in her justifications to accept the job, Ellen “speaks more with ardour than with logic, so hers is now the voice of passion” (215). And indeed later in the play she admits to Tom that it is her heart that made the decision not her head and that her desire to do science is not considered and cold; rather, it is “a passion, it’s intense… it’s sexy. It makes me fizz inside. To me it’s a form of rapture” (223). This blending of passion and science brings to mind Fenwick’s opinion that “science requires a warm heart” (182). Likewise, when she accepts Kate’s job offer, she explains: “It wasn’t an intellectual decision at all. It was my heart. I felt it beat faster when I thought of all the possibilities” (222). But Ellen is Fenwick’s evolved counterpart. Fenwick’s excessive pride in his radical ideas about the Enlightenment and the accompanying scientific advances requires him to be blind to their negative aspects, which makes him an idealist. However, Ellen is not as blindly passionate about science as Fenwick is and is very much aware of the negative aspects of scientific progress. As a thirteen-year old girl she dreamed of being God. Now she says to Kate, “You’re fifteen years younger than me and nothing frightens you. You still want to be God… You’re still in love with the work… but with me it’s been a long marriage and some of the romance has worn off” (170-171). Ellen seems like a moderate version of Fenwick who has been able to integrate her brain and her heart in a realistic way.

Tom, Susanna’s evolved counterpart, is now an educated intellectual in the realm of literature. He does not ignore intellectual questions but is the one who raises

them. Tom is the articulate voice of social conscience who wants Ellen to understand and accept the consequences of her scientific endeavor. He is no longer a passive vessel waiting to be filled up; he is rather an active being who has opinions of his own and openly expresses them. Unlike Susannah, Tom, whose life as a literary scholar is marked with passion, feelings, and emotions, seems to have been able to curb his heart with the strap of logic. He has also been able to balance the opposites.

The third pair of characters is Armstrong and Kate, who share the same quality: they seem to have no ethical boundaries to define themselves within. However, Kate is not completely evil. When Tom accuses her of being willing to dissect her own mother for the sake of scientific research, she responds, "Yeah, I probably would. But only if she was dead already" (223), bringing to mind Armstrong's theory that "The dead are just meat" (206). Still, she would not kill. So unlike the immoral Armstrong, she is merely amoral. Therefore, despite the fact that Kate is only slightly different from Armstrong, she too can be considered his evolved counterpart.

Barnett argues that *An Experiment* is "not about either/or but about both; about how seeming opposites coexist and how meaning is generated every time they collide" (209). In this sense, the characters that symbolize each dialectical pair are not in competition. They are in fact two halves of the same whole, rather than a definite dichotomy of incompatible tenets. In other words, "One does not cancel out the other. They form a complementarity, not a state of siege" (Stephenson 212). These oppositional pairs make up the two sides of the reality of futurity and progress; if we are to improve, we should give in to technological advances and simultaneously face their ethical and moral ramifications. By pairing the opposites in the play and showing them as complementary, Stephenson generates meaning and posits a model of the universe: as human beings, we embody dualities, but they should not remain static. We should learn

to integrate science with literature, brain with heart, and as Barnett puts it, "waver in our views of the conflicts between them" (216), as Stephenson's characters do and also as Edson's protagonist, Vivian, does (who eventually learns to integrate her head with her heart to guarantee her salvation).

Stephenson's message is that the march towards progress has as its core the opposition between science and ethics, which is not a choice but a condition of co-existence. We have to accept it and face it, as those who do not become hideous, as do Armstrong and Kate. Fenwick and Susannah's evolution into Ellen and Tom depicts their attempt to survive, as they ultimately recognize the necessity of the union of opposites. Ellen explains to Tom: "To me, an exquisitely balanced formula is a poem"; he responds, "So we're not that much different after all. Art and science, waves and particles, it's all the same thing" (Edson 223). As Stephenson's historical characters evolve into their more advanced contemporary versions characterized by the union of oppositions, the other dichotomies that define our existence as members of a scientific and technological society, namely ethics and scientific research, should also be accepted and dealt with as a necessary condition of life. In fact, this co-existence of oppositions is the only possible condition of life because the particles that make up not only us but also all of everything have at their core a paradoxical unification.

However, Stephenson is fully aware of the polyphony and with it the uncertainties that the union of the two opposites of science and ethics may present, and therefore leaves the ending dangling between two different envisagings of the future: one as utopia and one as dystopia.

3.3.4 The Ethical Uncertainty of Scientific Progress

Heisenberg's uncertainty principle introduced a radical indeterminacy in the perception of external reality as presented by subatomic elements because it revealed that there is no way to detach the observer from the observed making a single determinate meaning impossible to construct. In *An Experiment*, this uncertainty and the observer effect is presented in the depiction of the futurity and ethicality of science. In her depiction, Stephenson is not monolithic and completely negative, as Shepherd-Barr has argued (123); rather, similar to Wright's painting, her play is a "portrait of the uncertainty in an increasingly sophisticated technological age – two such ages, in fact – and how the challenges are borne variously by those depicted: the young, the mature, the idealistic, the cynical, the romantic" (Marks). In the painting, the same bird is interpreted by the figures in radically different ways: as a disturbance, a victim of science, a fascinating curiosity, and a promise to change the world for better/worse. Likewise, Stephenson's characters' perception of morality is widely different. Each character's sense of right and wrong originates from what they regard as most significant, which eventually results in the formation of opposite ideologies constantly clashing and colliding in the context of ethical questions surrounding science. In this way, scientific ethics turns into an object for dispute that simultaneously seeks and avoids resolution and refuses to be clearly defined. In other words, it changes depending on the way it is observed. This multiplicity of voices or polyphony offers a figurative parallel to the important place that observation occupies in the subatomic realm and the uncertainty that it brings with it. As Wright leaves his inspectors in doubt whether or not the experimenter is going to deprive the bird of air and therefore kill it, Stephenson also refuses to define scientific ethics or to determine the zone within which it should operate.

Another factor that contributes to this sense of uncertainty is the ambiguous

blend of hope and despair regarding the futurity of scientific progress that Stephenson offers in the final image of her play. Similar to the first scene, the last scene is also a recreation of Wright's painting; however, "this time Isobel, in her coffin, has taken the place of the bird in the air pump" (Stephenson 231). Isobel's death results in the mutation of Fenwick's blind optimism as now, instead of being a catalyst to change the world for better – like the dove – she is now a symbol of failure, the failure of scientific progress. The experimenter finally decided to kill the bird. As Fenwick kisses Isobel's forehead, he tells her: "The future looks less benign now, Isobel. We're a little more frightened than we were" (231). This is the first time that Fenwick seems less certain about his faith in the ability of science to be humane and progressive. Instead of heroically and confidently marching into a bright new century, the scientist finds himself "groping blindly over the border in bewilderment" (231). Here, Stephenson depicts scientists as "incarnations of Faustus at his worst" (Shepherd-Barr 123) and presents science as a corrupted practice that due to the unethicality of its practitioners will lead to an entirely dystopian future.

However, parallel to this negative image of the futurity of science, two hundred years later, the scientist rings in the new millennium with a fresh new outlook and a heart full of hope. Ellen and Tom decide to sell their house and move to the city, where Ellen can begin her experiments on pre-embryos, but they believe that this is a new beginning: "We'll start again. It could be exciting even… Let's go and put the champagne in the fridge" (Stephenson 229-30). Here, Ellen's acceptance of a job offer that involves working on pre-embryos and the fact that she and her husband, a moralist who is against her research, look forward to it with hope and excitement, show that Stephenson has refused to take the option of 'reprieving the bird' off the table and with it the possibility of science producing a utopia in the world. In fact, what she is trying to

say is that there is another dichotomy, hope and despair, that resides within the uncertainty and indeterminacy of the future that science is supposed to bring about and the ethical choices it is assumed to make. In other words, Stephenson suggests that the answer to whether the conflict between science and ethics can ever be resolved is something one "cannot know". Stephenson prefers to walk into the future with unsure steps, as her characters do: "Here's to whatever lies ahead… here's to uncharted lands… here's to a future we dream about but cannot know… here's to the new century" (231). Stephenson's refusal to provide a clear-cut answer and to leave the play open-ended suggests an understanding of the uncertainty that the quantum universe presents, and how it can offer an interpretation of human life.

As the above discussion suggested, *An Experiment* uses the science of anatomy and biology, especially the human genome project, in order to discuss the non-scientific issues of the relationship between moral ethics and scientific ethos and the future that scientific research has to offer. The tangential role that Stephenson assigns to science in her play places it in the first category of science plays, namely 'science as supporting character'. Stephenson creates a world in which historical and contemporary characters, with two hundred years' time difference, are given the chance to be on the semi-circle space of the stage together. In doing so, she blurs the thick Newtonian lines between the past and present and depicts them as a unified temporal unit. The nonlinear temporality of the play creates a narrative structure that figuratively parallels the way electrons leap in nonlinear fashion between different time orbits. Stephenson's illustration of past and present characters as personifications of concepts which are put together in the form of complementary oppositional pairs, can be interpreted as a metaphorical reconstruction of the complementarity principle and the network of entangled entities created as a result of connections across vast temporal distances; it is a figurative representation of

the quantum notion of entanglement. And finally, she places an unresolvable dichotomy of hope and despair at the heart of the futurity of scientific research and depicts scientific ethics as an objective concept open to dispute and interpretation, which, it can be argued, apply the uncertainty principle and the observer effect to the level of human interaction.

In this chapter, the intersection between the post-quantum reality and contemporary science plays was investigated with reference to two examples in which science is pushed to margins to make nonscientific topics raised by science and scientists the starts of the stage. The following chapter, however, will discuss this impact with reference to those science plays that have placed science at their core.

Chapter 4

Science as Leading Character

4.1 Introduction

The previous chapter explored two first-category science plays within the context of the new physics paradigm presented in Chapter 2. This chapter uses the same paradigm to discuss two science plays (Wertenbaker's *After Darwin* and Djerassi and Hoffmann's *Oxygen*) that belong to the 'science as leading character' category. In these plays science and its practitioners become the atoms around which the other elements of the plays orbit. Wertenbaker and Djerassi/Hoffmann draw on actual historical scientists, narrate their stories, dramatize the motivations for their science and its implications for themselves and for those outside the circle of science, and accurately and plausibly explain it or use it metaphorically, to turn the stage into a unique space where science becomes the leading character, tapping its foot right at the centre of the stage, visible and unstoppable. However, *After Darwin* and *Oxygen* can go far beyond being analysed only within the context of scientific ideas that they engage. The implications and issues that they present and the way the stage is used to dramatize them clearly reflect the main features that characterize the new perception of reality validated by the new physics. Wertenbaker and Djerassi/Hoffmann's plays can be interpreted as microcosmic representations of the laws that structure the whole universe at its most basic level.

4.2 The World After Darwin: Identity and Ethics in Timberlake Wertenbaker's *After Darwin*

Timberlake Wertenbaker's *After Darwin* was staged for the first time at the Hampstead Theatre in London in 1998, the year which also saw the premier of *Copenhagen* and *An Experiment*. On the first night of the performance, reviewers suggested a connection between *After Darwin* and those two plays, and following Michael Billington's proposal that "Our post-Utopian, post-religious, postmodern world is looking to science to provide the moral conundrums that are the essence of drama" (27), acknowledged the growing dominance and status of science within theatre.[37] Although *After Darwin* did not achieve huge success onstage or in print (not doing as well as *Copenhagen* or *Arcadia*), the central place that science occupies in the play demonstrates a vital if overlooked contribution to the genre of the science play. *After Darwin* dramatizes how the scientific discoveries of Charles Darwin have influenced the state of our lives, in which ethical principles are constantly being threatened by humanity's struggle for existence. Wertenbaker effectively and beautifully explores topics such as natural selection, adaptation, the survival of the fittest, mutation, and extinction, in relation to ethics, and draws the social map of a society whose inhabitants are incapable of moral choice; rather, they are driven by, as Sara Freeman puts it, "the biological imperative to select and survive" (214). But *After Darwin* has not only contributed to the genre of the science play; rather, the connection that Wertenbaker artistically establishes between Darwinism and the reality at the heart of human existence, that is the indomitable spirit of mankind's will to survive, also provides a very suitable context to explore another kind of reality, namely the post-quantum reality, but this time with relation to the microcosm of *After Darwin* and its inhabitants.

Parallel to her exploration of ethics within a Darwinian paradigm, Wertenbaker

[37] See the reviews by Charles Spencer for the *Daily Telegraph* on 15 July 1998, Sheridan Morley for the *Spectator* on 18 July 1998, and Benedict Nightingale for the *New York Times* on 9 August 1998.

uses the same framework to launch into a long discourse on identity by examining its social and biological construction. The play features characters with floating identities who are forced to take roles simply to survive, as though identity were merely a question of persons performing themselves. The characters in Wertenbaker's play construct their own identities by incorporating within themselves dominant social norms and institutions as an act of survival.

According to T. H. Huxley, "*The Origin of Species* (1859), for the first time, put the doctrine of evolution, in its application to living things, upon a scientific foundation" (101). In this book, Darwin formulated the basic controlling and determining mechanism according to which evolution takes place, and provided a broad foundation of evidence to support his theory. The essence of Darwin's ideas is a phenomenon known as natural selection, according to which if any being, in the act of the struggle for existence, changes, "however slightly in any manner profitable to itself, under the complex and sometimes varying conditions of life, [it] will have a better chance of surviving, and thus be naturally selected" (97). Those that are best adapted survive as the fittest, while others become extinct. However, the physical and behavioral changes that make natural selection possible are caused by mutations: accidental, random heredity factors that occur regardless of the benefit or loss to the organism. Nevertheless, in the process of natural selection, Darwin argues, "favorable variations would tend to be preserved and unfavorable ones to be destroyed the result of which would be the formation of new species" (438). Wertenbaker's play is about the young scientist whom Captain Robert FitzRoy takes along on the Beagle to a voyage to South America and the Galapagos Islands, during which he collects the data that formed the basis for these theories.

The play is one of the best examples of science plays that use realistic science –

in this case the theory of evolution (Darwinism) – metaphorically, providing an accurate and plausible description of it, to make science the central character on stage. Wertenbaker drags the originator of evolution from history and brings him on stage to accurately explain his science, and then creates a group of fictional characters that fully feel its implications in their lived experiences of ethics and identity. In doing so, she uses Darwinism as a mechanism to discuss the human condition and, to use Shepherd-Barr's words, literally enacts the idea that it engages with (6).

Similar to *An Experiment*, *After Darwin* alternates between the past and present, with the same actors doubling in the two different time periods, but the latter moves slightly forward and places its historical characters in the mid-nineteenth century. The play begins as a conventional history play focusing on Darwin and FitzRoy. However, in Scene 2, when Millie, a Bulgarian refugee director, suddenly intervenes, it is revealed that the nineteenth-century scenes are in fact the rehearsal of one play inside another. The historical scenes concern the philosophical discussions around the theory of evolution between the extremely religious Victorian moralist FitzRoy and Darwin, the young passionate scientist with revolutionary ideas, during their journey on the Beagle. The contemporary scenes, on the other hand, feature Millie, two actors – the young opportunist Tom and the middle-aged Ian who leads a strict moral life, playing Darwin and FitzRoy respectively – and an African-American playwright, Lawrence, rehearsing a play about Darwin and FitzRoy's voyage. In the interior play, Wertenbaker's focus is not on recreating the physical conditions of the voyage; rather, the goal is to recreate the ideological framework within which Darwinism operates. The exterior play is also structured in such a way that it becomes a direct commentary on the impact of Darwinism on contemporary human life, its ethical imperatives and the sense of self.

The dramatic tension of each time period gradually increases as the play

progresses. Darwin and FitzRoy's relationship becomes tormented because FitzRoy believes that, as a result of Darwin's ideas, the fixed certainties with which people have long lived, God and man, are thrown into disarray (Billington 27). He eventually comes to feel that he was responsible for the Darwinian revolution, which destroyed forever humanity's faith in God, and so kills himself (FitzRoy did indeed cut his own throat in 1865). Meanwhile, Tom is offered a part in an action movie by which he can realize his dream of becoming a film actor. However, to do so, he must quit the play, which means that it will have to be cancelled. To save the production, Ian emails the producer of Tom's movie with the false information that he has AIDS.

Surprisingly, many of *After Darwin*'s critics have viewed Wertenbaker's deployment of the device of the play-within-the-play as a serious drawback, arguing that it makes FitzRoy and Darwin's story secondary and adds unnecessary complexity to the play.[38] However, these critics have got it wrong. The simultaneous depiction of the formation of the theory of evolution in the nineteenth century and its enactment through the behavior of the contemporary characters in the twentieth century enables Wertenbaker to depict the implications of this theory on the future. It gives her an appropriate context within which to dramatize the applicability of the Darwinian paradigm as an apt metaphor and frame of reference with which to structure and define the human condition; a condition where the struggle for existence has overshadowed not only our ethical and social life but also our sense of self and identity. Moreover, the device of the play-within-the-play allows Wertenbaker to feature characters that, despite their temporal and spatial differences, have to deal with the same ethical and identity issues. She not only suggests the durability of the theory of evolution but also its

[38] See the reviews by Spencer, Morley, Susannah Clapp for the *Observer* on 19 July 1998, Robert Butler for the *Independent on Sunday* on 19 July 1998, and Alastair Macaulay for the *Financial Times* on 18 August 1998.

inseparability from human life: the fact that it actually defines our existence as human beings.

In *After Darwin*, Wertenbaker puts the nineteenth-century Darwin to use for the twentieth century, and raises questions that challenge her audience's conscience and reasoning in deciding which is more certain and therefore wins in the battle between the two certainties of ethics and survival. Is there really a winner or are we only supposed to float in a world full of uncertainties? This question, along with other questions that Wertenbaker asks her characters and audience in *After Darwin*, enables us to discuss the play with reference to the parameters of the new physics paradigm.

4.2.1 No Chronology, No Linearity

An analysis of the structure of *After Darwin* reveals an elaborate pattern, and shows how the past and present and here and there of the play gradually constitute a continuous whole. Wertenbaker' play embraces a relative temporality/spatiality in which, similar to Einstein's space-time universe, the distinction between different temporal and spatial units is perceived as not absolute. Throughout Act I the scenes either belong to the past or to the present. The only exception is the final scene, in which the two periods occupy the stage together: an interaction between Darwin and FitzRoy with the stage direction "*Lawrence and Millie, watching*" (Wertenbaker, *Darwin* 34). In Act II, the changes between the two times are not as clearly marked as in Act I and the interjections become more recurrent. This act begins with the constant interruption of the dramatization of FitzRoy and Darwin's 1830 meeting by contemporary scenes. Then the past/present alteration pattern becomes regular once again, but unlike Act I where the scene changes separate the two periods, the scenes

change directly from the past into the present, making the interaction between the two time periods even closer. The pattern of alternation ends in Scene 7 and the two periods collapse and merge, with the historical and contemporary characters occupying the stage together. In their immediate and constant travel from one time period to another, the audience is also instantly transferred from a ship, the Beagle, in South America or the Galapagos Islands, to a rehearsal room, breaking the absolutism of space alongside of that of time.

After Darwin's fast and fluid movement between past and present and here and there creates a lump of different units of time and space, but also causes the fragments of the historical and contemporary narratives to constantly interrupt each other, and gives the play an episodic, nonlinear narrative structure. The natural flow of historical narrative is constantly interrupted by contemporary characters' comments on the play, and the linearity of the contemporary narrative is shattered every time the historical events are enacted on stage. *After Darwin*'s eschewing of linear narrative structure requires considerable effort on the part of the audience as it finds out about the fate of the historical characters and the life of the contemporary ones in a discontinuous, chaotic fashion; it is the audience's responsibility to put the fragments in linear order. This process of discovery is further complicated due to the non-chronological development of the historical narrative. The play opens in 1865 with FitzRoy threatening Darwin with a razor and then drawing it up to his own throat to slit it. The next scene precedes this scene by forty-four years, enacting the two Englishmen's energetic first meeting, which premises a mentorial friendship with FitzRoy as guide, based on a mutual love of nature. The closing scene of the play is a reenactment of the first scene but with revisions. In a more heated intellectual exchange, FitzRoy, who believes that Darwin has betrayed not only their relationship but also society's deeply

needed religious/moral order, threatens him with a gun, to try to get him to abandon his ideas. The historical narrative therefore begins at the end and from there first moves backwards and then forwards in time to narrate its story in a non-chronological, fragmented fashion. The non-chronological nature of *After Darwin* therefore abandons narrative linearity and requires its audience to put the fragments in the right order to construct a linear narrative. The constant disappearance and reappearance of the narratives when confronted with each other's fragments, and the historical narrative's repeated jumps from one time frame to another, mimic the electron's movement between orbitals inside an atom, in another example of how the ideas of new physics have provided a rich metaphorical vein for the authors of science plays to mine. *After Darwin*'s constant time/space travels between two different time periods provide an appropriate framework within which to discuss the quantum entanglement principle.

4.2.2 Darwin, Connection and Opposition

As the two historical periods develop in parallel, a sense of the inseparability of Darwin's theories from the state of human life and ethics also develops accordingly. While watching Darwinism gradually take shape on stage, the audience confronts Wertenbaker's microcosm of characters who are put in situations in which, despite their temporal and spatial differences, they display similar reactions that can only be justified within the Darwinian paradigm; the fact that regardless of our time, place, race, gender, and culture, the dominant force shaping our existence as human beings is the struggle to survive and to avoid extinction. As a result, the definitions of concepts such as ethical integrity and authentic identity can easily change, depending on the adaptation that the act of survival calls for. At one point in the play Ian says, "Millie, the moral dilemma is an overspecialized refinement that leads rapidly to extinction" (Wertenbaker, *Darwin*

54). This coincides with Millie's opinion that "The truth is not a good survival tool. It makes you vulnerable" (51). The theory of entanglement indicates that two entities, once they interact with each other, remain entangled despite whatever vast distances coming between them. In *After Darwin*, the similarities that Wertenbaker establishes between her historical and contemporary characters within the Darwinian paradigm create a network of connections that lead to the characters becoming entangled across centuries and continents.

The struggle of FitzRoy, the historical moralist character, to persuade his companion Darwin not to publish his supposedly anti-God theories is reflected and reproduced in the struggle of Ian, the contemporary moralist character, to persuade his fellow actor Tom not to accept the film offer. For both FitzRoy and Ian, adaptability is not the governing principle of existence. FitzRoy is not open to new ideas and prefers his own outworn Victorian mindset, while Ian has made a firm decision to remain on the stage practicing his own 'old-school', ornate acting skills (44). He even ruined his chances of getting a name in the film industry by rejecting a part as a serial killer in a very successful movie (44). Similar to FitzRoy, Ian is a man of principle who values ethics and who has tried to live by his own moral code. He believes that it would be morally reprehensible for Tom to leave the play and therefore tries to cling to his ethical obligations to convince him:

> You're part of a culture that nurtured you, that gives you your identity and protects you from despair. You're playing a man of extreme decency and you're taking the most superficial reading of his own words to excuse your disgusting, criminal, your tawdry – … You've formed relationships here, to Millie, to me, to Lawrence. You have an obligation and you do know what that word means because under that camouflage of idiocy is a man of talent, who somewhere, however dimly, believes, believes… (46)

Tom, on the other hand, is a young, narcissistic, ambitious actor who is eager to experience the new media. He is ready to further his career and to accept a part in a

trashy movie at the expense of the production's ruin. When Ian strongly objects to his decision, Tom justifies it in Darwinian terms:

> IAN. You are not some animal foraging for food.
> TOM. That's what Darwin's saying here, isn't it? … I'm hungry, Ian, I want to go where there's lots of food. (45)

Similarly, he does not accept Ian's definition of morality – "I don't understand that word, Ian" (45) – and instead argues that as human beings they are all driven by their biological impulses, forcing them to select and survive, and therefore are incapable of making moral choices. He is "cynical, selfish, stupid, immoral and want[s] only a good life" (26), and is prepared to sacrifice not only the production but also his friends. Tom is, in fact, Wertenbaker's perfect model for an evolutionary version of the human species able to develop an organic relationship to the environment that he inhabits merely to survive. He is a Darwinist who plays Darwin, justifies himself in Darwinian terms, and enacts Darwin's theories.

However, Wertenbaker's moralist characters are not so different from her Darwinist characters. They too are not immune to the struggle for existence. Ian is an old actor who has been without work for two years due to his stoicism, and now he is in danger of becoming professionally extinct. He feels that his ornate skills, that characterize a classically trained actor, have become, to use Nicholas Ruddick's words, "like the cumbersome antlers of the vanished Irish elk" (128). Since he has already ruined his chances of getting a name in the film industry, this play is his only chance to survive, to save both his career and his acting skills. Eventually he undertakes the subterfuge of emailing the producer of Ian's movie with false information, with the justification that he can betray his moral code in order to achieve moral ends. In doing so, Tom will quietly stay and continue with the play and everyone will be better off, including himself. So here, Ian's actions are driven by his need to survive. In Act 2

Scene 6, Ian also justifies his act within a Darwinian paradigm: “I don’t want another two years without work. I want to survive, I want Millie to survive, I want this to survive… Just a chance, I thought – so I broke my code, like FitzRoy” (Wertenbaker, *Darwin* 65-66).

And indeed, the character Ian is playing also breaks his moral code just to survive and avoid extinction. The first and the last scenes of *After Darwin* refer to what Feldman considers as FitzRoy’s “sense of historical injustice” (175). The audience sees him in the first scene drawing a razor up to his throat, and while doing so, lamenting “I leave nothing behind” (Wertenbaker, *Darwin* 1). In the final scene also, FitzRoy grieves over the sparseness of his legacy: “I left nothing behind… A light foam or ridicule and irritation… A puff of weather… The dark side of the light” (72). Young Darwin’s outstanding discoveries onboard the Beagle have removed from popular memory the history of FitzRoy’s accomplishments onboard the ship he captained. As a man who aimed “to change the history of the world”, FitzRoy wants to be “remembered as someone who benefited mankind” (31), but his ambition is frustrated by his choice of companionship. Moreover, as an extremely devoted Christian, he does not want Darwin’s naturalist, areligious paradigm to be the winning one – in the Kuhnian sense of the word – in the battle of ideologies. He therefore must stop the man he took with him on the Beagle from publishing his theories so he will not be responsible for “unleashing the faith-destroying Darwinian revolution upon the world” (Ruddick 127). This is why in the revision of the play Lawrence decides that a man like FitzRoy, a Victorian gentleman who swears on the Bible (Wertenbaker, *Darwin* 64) and is a man of faith, does not simply remonstrate with Darwin using words only; rather, he aims a gun at him, forces him to go down on his knees, and threatens him, an unarmed man, unless he swears to forgo his inquiries into evolution (63-66). What Wertenbaker is

suggesting here is that despite their firm belief in ethical principles and moral codes, Ian and FitzRoy, just like Tom, cannot operate outside the Darwinian paradigm and the defining principle of their existence: the will to survive. In this light, their act of ethical betrayal becomes an act of adaptation in order to be naturally selected and eventually to be among the fittest, and thus to survive. This process of entanglement that Wertenbaker introduces between the past and present characters, with the context of their Darwinian similarities, is a figurative reproduction of the quantum notion of entanglement where particles become linked regardless of the distance.

Ian and FitzRoy are not the only contemporary characters whose moral views have conformed to their need to survive. Millie also has to go through the same transformation process. She knows that her survival depends on the success of Lawrence's play, because in this way she can prove that she is talented enough to be a productive member of British society and consequently can make a case for permanent residency in the United Kingdom. She therefore decides to conceal the truth that she has never directed a play before. Her only connection to the theatre was serving as a cleaner in a state theatre after she was expelled from the science department in Bulgaria due to her Turkish heritage. She decides to conceal from the cast the truth about her background and her real motivations in staging the play. As quoted earlier, she states that "The truth is not a good survival tool. It makes you vulnerable" (51). The unethical practices of Wertenbaker's characters in favor of survival reflect the remorseless logic of Darwinism:

> FITZROY. We lose our moral sense and are no better than animals.
> DARWIN. We are animals. (59)

Adding Millie to the play's victims of survival, Wertenbaker allows the greedy spider of Darwinism to expand the scope of its sticky web of connections across centuries and continents and hunt the playwright's past and present characters. This distanced

connection is reinforced by the fact that the same actors that play Tom and Ian also play their historical counterparts. Similar to *An Experiment*, the actors' bodies function as teleporters that instantly connect characters two hundred years apart. This can be interpreted as another metaphorical application of a principle from quantum science: in this case, the connections that particles make no matter how far apart they are.

Darwinism can also be the source of another quantum-related discussion in regards to Wertenbaker's play: the complementarity principle. Under the heavy shadow of this theory, a series of oppositional pairs emerge that operate within the domain of the characters' sense of identity. In their struggles to survive they end up acquiring hybrid identities, as a result of their attempts to fit into the host environment; identities at the center of which there are complementary dualities, polarities, or duplicities that are also invoked in quantum experiments, which are both mutually exclusive (particle/wave) and mutually necessary.

In Wertenbaker's play we meet, as Sophie Bush explains, "a cross-border adult, a more troubled species" (201), who has to deal with a range of threats and challenges. The best example of this phenomenon is the Bulgarian refugee, Millie. Before coming to Britain, she has had to suffer the consequences of a war of ethnic cleansing in Bulgaria, due to her Turkish heritage. Mistreated in her own country, she escapes to England, where she has to deal with the instability of a cross-cultural existence on a daily basis. To join the English species and survive, Millie knows that she needs to adapt to the new environment. She therefore learns new codes, a new language, and strives to appear "more British than the British" (Wertenbaker, *Darwin* 26). In order to do so, she believes that she must remove all the elements of her foreignness, such as her accent. Tom tries to persuade her not to "lose the passion in [her] vowels" (27), but Millie is determined:

> MILLIE. I can't pass for British unless I get rid of them.
> TOM. What a sacrifice.
> MILLIE. Not for survival.
> TOM. (*correcting the 'u' of survival*) Survival. (28)

She has also sacrificed her Bulgarian name, in favor of the English-sounding Amelia (51). However, it seems that Millie has not been able to fully adapt to her new environment (50-52) and is in the same condition of hybridity in England that she was in Bulgaria, where she was torn between her Turkish heritage and her Bulgarian nationality. The same features that are essential characteristics of Bulgarian identity – intense passion and emotion (24) – also exist in her working methods. She "*throws herself down on Ian's feet*" to beg him to follow her direction. When Ian disapproves of this, saying "This is no way to direct", she replies, "It is in Moscow" (10). She therefore exhibits the same features that she has striven to discard.

However, Millie's inability to erase the signs of her foreignness in order to seem British takes a positive form for her. Since Millie's governing principle of existence requires her to adapt in order to survive, she decides to reinvent herself. She blends different facets of her past and her present into a new hybrid identity for the future because she believes that her Balkan qualities, her "intellectual energy and passion", will supplement her new identity and enable her "to thrive in the West" (55). She understands every word of what Darwin says because she has read all of Darwin (50), and she combines her intellectual understanding with passion. In Act I Scene 3, she wants to see an effective depiction: "I see emotions in these lines… I see two men who embrace". When Ian disagrees with her, saying "Maybe in Bulgaria", she explains, "In Bulgaria they would take a knife to their arms and mingle their blood… they would be fighting in caves and forests against the Turks" (9). Ian accuses her of shaming them "with the excitement of her history", but Millie refuses to accept the identification: "It is not my history any more, this is my history" (9). Here, Millie, a Bulgarian refugee,

presents herself as a British national and in this way asserts ownership of English history to validate her newly adapted identity. This is why she desperately needs the play to open, to help her with the ratification of the tenets of her existence. Millie's desire that the two actors embrace is in fact a "desperate bid to rewrite nationality, to render it an act of interpretation, to infuse English history with Balkan passion, to see a new life form emerge" (Feldman 176-177); a new life form that simultaneously makes her foreign and British, familiar and strange, outsider and native. She places herself among the fittest, through the process of natural selection, preserving favorable mutations (Balkan passion and intellectual energy) and eliminating the unfavorable (accent, history, name) to guarantee her survival. Like a particle whose contradictory states coexist with each other, the doubled differences defining Millie's identity also reconcile with each other to make her survival possible.

Another character that can be discussed with reference to the intersection between identity and the complementarity principle is Lawrence, who also has to acquire a hybrid identity. He was raised among racial tensions in Washington, D.C. When he was eight, his mom took him out of school and separated him from dissatisfied black youth to live on white writers only:

> I was beginning to go wild, beyond anger as you say – and she locked me up with books, everything she could lay her hands on. Here, she said to me, here's your friends; Shakespeare, Milton, *Moby Dick*, that's the only gang you're ever to hang out with. She put in extra hours to hire tutors. No black writers. No writing on slavery. When I told her about Caliban she tore out *The Tempest* from my collected Shakespeare. (Wertenbaker, *Darwin* 57)

Lawrence is not only cut off from his African-American fellows, therefore, but also from the canon of his ethnic heritage. He acknowledges the cancellation of his own heritage as follows:

> Blind kings, barren women, runaway children and castaways peopled my childhood… they became my ancestors, these loved figures carved from the crooked timber of humanity… lining the shelves of my memory – a parallel

> evolution, where imagination multiplies… Their legacy, empathy, complexity. (72)

Just like Millie, who voluntarily eliminates her accent, Lawrence's mother removes all traces of her family's cultural heritage as an act of survival for her son. In other words, she destroys her son's unfavorable mutations in order to guarantee his survival in the new environment. In her determination to force Lawrence to transcend the circumstances of his birth and to adapt the cultural mores of another race and class, she has imposed the burden of biculturalism on him. Lawrence, like Millie, has acquired a history not of his own and has adapted, in Feldman's words, "an imported tradition" (177). Despite his belief that thanks to his education he has been able to successfully forsake his ancestors and adapt a new culture, Lawrence also suffers the stresses of biculturalism. He says that one of the reasons why he decided to write the play was to narrate the story of the three natives of Tierra del Fuego who were "the first people to suffer the stresses of biculturalism" (Wertenbaker, *Darwin* 32). Lawrence's narration of their story is an attempt to tell his own bicultural history as a black man in America who tried to escape his situation by reading white literature. He, in fact, doubles the examples of the natives of Tierra del Fuego and is the conduit for their story. Lawrence now owns a hybrid identity, at once black and white, wronged by racial prejudice. He is "a hybrid, a completely new form" (56), one that mixes elements of his suppressed and acquired identities together.

In his description of the perfect adaptive evolution of Galapagos finches, Darwin creates a model to which Wertenbaker's character correspond: "In this stage, this brave new world, isolated from the rest of the continent, the islands, themselves isolated from each other… there began to emerge birds so different from their forebears… that they must, in truth, be called a-new-species" (36). Lawrence and Millie are therefore a new species with a hybrid identity; they neither belong to what is their own nor to what is

not their own. They have acquired a new identity with two opposing but complementary modes of realization that form their very beings.

Millie and Lawrence's confused identification with their native and non-native cultures is mirrored in the interior play. At the start of the voyage, FitzRoy reveals to Darwin his goal in embarking on such a long journey. He tells him that he aims to prevent both nautical and spiritual shipwreck by sufficiently mapping the coasts of South America and describing God's work (7). He also intends to convert the savages they encounter en route to English culture and religion, with the purpose of eventually 'redeeming' them. The prime example of these "miserable and savage creatures" (2) is Jemmy Button, whom he captured in Tierra del Fuego, educated in England and repatriated to his native culture. "Jemmy Button recognized his tribe" (31), Lawrence explains, "but could no longer speak his own language and his mother and his brothers refused to acknowledge him" (32). The attempt to repatriate Jemmy produced disastrous results, and when FitzRoy returns to Tierra del Fuego the year after his voyage with Darwin, he discovers a miserable Jemmy Button who refuses to talk to him until he is fully clothed. He then tells "a tale of abject treatment by his tribe and family" (32). Jemmy's tribe have rejected his English influence and treated him very badly. However, he refuses to return to Western civilization with FitzRoy. Lawrence explains: "He had adapted Englishness with total enthusiasm, but had then readapted the customs of his tribe with equal commitment, thus becoming perhaps one of the first people to suffer the stress of biculturalism, a condition which was to reach epidemic proportions in the late twentieth century" (32). Jemmy Button also possesses a hybrid identity, simultaneously civilized and uncivilized, accepted and rejected, English and Fuegian.

Wertenbaker's strategy of having Lawrence tell Jemmy's story further highlights the connection that is created between the contemporary characters and the historical

characters across time and space. In the domain of Wertenbaker's play, the Darwinian paradigm becomes the only accepted context within which the state of human life should be examined. A domain in which, amidst all the cultural and racial differences, the only similarity that connects all the characters is the necessity to absorb and unite oppositions; an act of survival that defines their existence as human beings the same way as it does for quantic entities. Regardless of their temporal and spatial differences, in other words, Wertenbaker's characters become particles that, while carrying paradoxical complementarities within themselves, connect and entangle with each other within a network of similarities defined by Darwinism.

By using theatre as a medium to translate Darwinism, Wertenbaker creatively uses it as a metaphor for the theory of evolution. When Tom is surprised by the fact that "they teach evolution in drama school in Bulgaria", Millie replies, "Why not? The essence of drama is conflict, no? Struggle: evolution" (Wertenbaker, *Darwin* 50). This frames the conventions of this relationship in the play. In the playwright's eye, biculturalism is a kind of acting. Struggling to survive, the characters in the play adapt and shed identities. Shepherd-Barr argues that "In its own subtle manifestation of 'conscious theatricality' the play conveys the idea that the demonstration of evolution, specifically the idea of adaptation, is acting" (117). In the course of the play, we realize that Millie has been acting, as she was not a theatre director but a janitor working in a theatre. Tom's acting is double: first as an actor onstage and second in his deception of his fellow actors. Lawrence and Jemmy have both lived in two different cultural arenas through role-playing. Ian and FitzRoy also are more like two actors playing the roles of two men of principles. The characters in *After Darwin* find acting to be the best strategy to successfully adapt to their new environment, and this very intersection between acting and adaptation is what establishes a close connection between the scientific

theory of evolution and theatre. Shepherd-Barr explains, "The theatre also demands adaptation, not just as you prepare each character, but during each performance and throughout the whole run. It is a process of continuous flux and change" (117). It is the same for *After Darwin*'s characters, who constantly evolve and adapt on Wertenbaker's stage. But where do all these struggles to survive lead to? That is a question that Wertenbaker decides to raise at the end of her play.

4.2.3 Which One is to Survive? Ethics or Darwin?

The uncertainty that characterizes the quantum realm and the significant role that the act of observation plays in it can be explored in *After Darwin* with relation to the characters' perception of the priority of ethics over survival or vice versa. All Wertenbaker's characters consider the act of survival to be the main principle governing their existence, to the extent that even their moral principles can be defined within the context of adaptation and survival. Over the course of the play the struggle to be fittest and therefore to survive is the only fixed certainty that the characters accept and believe. Under the microscope of Wertenbaker's characters, the Darwinian struggle for existence is viewed as the only certain truth that authorizes the sacrifice of ethics in favor of survival. However, Lawrence is the only character who decides to do otherwise, and sacrifices the Darwinian perception of human existence for the sake of his moral principles. From his standpoint, a necessary evil does not oblige people to go against their morality. This is why at the end of the play, when he learns about Ian's deception, he decides to stop the production, despite the fact that Tom is now happy to play the role. Lawrence cannot approve of Ian's act because he believes that he is responsible for his integrity (Wertenbaker, *Darwin* 68) and that if he allowed the play to continue on

such terms he would feel his work was contaminated (69). Millie tries to change Lawrence's mind, saying that his mother is coming to see the performance, but Lawrence replies, "If there's one thing a black American woman from Washington, D.C. knows, it's the difference between right and wrong… You have to stand up for your principles" (68). When she tries to make him see how deeply everyone needs this show to go on to survive both spiritually and economically, he replies, "Don't make me betray my moral code… It's what I hold on to, Millie, it's what makes me hold my head high" (70). As a result of Lawrence's decision, the production will terminate and with it Millie's hopes of staying in the United Kingdom, Tom's film and theatre career, Ian's chance to save his 'old-school' acting style, and even Lawrence's opportunity to prove to his mother that her "philosophy of education, his indoctrination in the English literary canon, and the cancellation of his own heritage" have worked (Feldman 177). Lawrence's decision will also affect the fate of FitzRoy, who as a failed character, marginalized by history in comparison to Darwin, had his one chance of being reinstated in history through Lawrence's play.

When Lawrence informs Millie of his decision to stand by his moral codes, Millie replies, "Ian's broken his, Tom never had one, what makes you think you can survive without getting your hands dirty?" (Wertenbaker, *Darwin* 70) This is where Wertenbaker raises one of the central quandaries of human life: in a world dominated by cruel Darwinism and the struggle for survival, which is the right path to take? To go down the road of survival and betray ethics, or to stand by moral principles whatever the consequences? Which is the right decision to make "in this twenty-first century, in this third millennium, [where] human beings are in trouble in some way. They have lost their certainty[?]" (Wertenbaker qtd. in Freeman 201) Wertenbaker does not provide an answer to this question, instead letting the audience's conscience and reasoning

determine how the play should end. Shepherd-Barr explains that Wertenbaker only shows the audience members the problem and then asks them "to ponder the possible solutions and finally come to understand that they have a huge responsibility in their hands: no less than the fate of earth" (119). She wants them to decide which one is to survive, Darwin or ethics? In doing so, she lets characters and the audience's observations of ethics and survival take control that introduces a polyphony and multiplicity of voices into the play. The interference and the clash of these different observations allows for a richness of possible meanings that eventually posits a radical indeterminacy at the heart of *After Darwin*.

Wertenbaker brings this uncertainty to the surface in the final scene in which she directly addresses the audience and invites them to decide what decision Lawrence should make. Darwin/Tom is sitting at his desk speaking lines from *On the Origin of Species*, when FitzRoy/Ian enters carrying a bible, a razor, and a bowl. FitzRoy then begins to read texts from Genesis in despair. Millie and Lawrence are in the Darwin museum in Down House and Millie is reading the titles of the books about Darwin on the bookshelves, the same books that gave her the intellectual energy and passion to survive in the West. While Millie and Darwin continue their litanies, FitzRoy directly addresses the audience, lamenting the paucity of his legacy, with Lawrence staring at him. He then grasps Lawrence's shoulders, pleading with him to "give [him] substance" and asking Lawrence to find him and give him room (Wertenbaker, *Darwin* 73). FitzRoy wants Lawrence to reinstate him in history, to help him survive historically. Then, as their fragmented speeches gradually decrease, all four characters "look at one another and out towards the audience" (73), as if inviting them to be a part of their play and decide the fate of these characters: should Lawrence discard his moral principles and let the play survive, and with it Millie and her intellectual passion and FitzRoy's

historical heritage, or should he stand by his ethics regardless of the consequences? This is the question that Wertenbaker's audience is supposed to answer. Here, the collision of the characters' opposing perceptions regarding the priority of ethics over survival and vice versa introduces a void of uncertainty into the play and consequently into the mind of the audience. The uncertainty that defines human existence is a microcosm of the uncertainty that characterizes the whole universe, and the polyphony presented in the play emphasizes the role that observation plays in our perception of external reality. Here, Wertenbaker allows the voice of her characters and audience heard and in doing so dramatizes the uncertainty that defines the basis of everything in the universe.

After Darwin is a second-category science play in which the scientific theory of evolution or Darwinism is used metaphorically to provide a commentary on human condition as defined by a competitive struggle to survive. Wertenbaker's metaphoric use of Darwinism places science at the centre of the play, around the orbit of which the other elements rotate. There are a number of ways in which the play's narrative can be interpreted as a figurative representation of the principles of quantum science. *After Darwin* reproduces an Einsteinian perception of time and space by the simultaneous presentation of the past and present and here and there. In doing so, an episodic narrative structure is created that unfolds in the same fashion as electrons leap from one energy level to the next. In the same way that different individual particles are bonded, so that even when separated by large distances they can communicate instantly, Wertenbaker's characters connect and entangle with each other through the device of Darwinism. This scientific theory causes the reconciliation of opposites (the complementarity principle) in *After Darwin* by forcing the characters to acquire a hybrid identity simply to survive. The characters' multiplicity of observations of the superiority of ethics over survival or vice versa introduces an element of uncertainty

into the play, regarding which one should be sacrificed for the sake of the other, resembles microcosmic representation of Heisenberg's uncertainty principle and the importance of the observer. It is surely clear that a sense of how the new science has affected our understanding of human existence is a deep source of influence on the play. The following section explores another play in the 'science as leading character' category, and provides further evidence of the framework of new physics.

4.3 The Search for Discovery in Carl Djerassi and Roald Hoffmann's *Oxygen*

It was not until the mid-eighteenth century that scientists became aware of an element in air associated with breathing and burning. In 1774 the English natural scientist Joseph Priestley isolated that element. Following his discovery, in 1775 French scientist Antoine Lavoisier coined the name of the new component: 'oxygen', meaning 'acid former'. However, three years prior to their discoveries, Swedish chemist Carl Wilhelm Scheele had discovered a gas that he called 'fire air' with similar characteristics to oxygen. There is considerable historical debate on who discovered oxygen and when, and this debate is the context of a play written by two renowned scientists, Carl Djerassi and Roald Hoffmann, who after receiving all possible honors in their own scientific fields, both pursued literary careers.[39] The world premiere of *Oxygen* happened on April 2, 2001, at the San Diego Repertory Theatre. This event was in conjunction with the national meeting of the American Chemical Society and most of the audience were scientists of that field who reacted very positively to the play.

[39] Carl Djerassi, known as the father of the birth control pill, was the developer of antihistamines, the founder of biomedical companies, a novelist, and a playwright. Roald Hoffmann won the Nobel Prize for Chemistry in 1981 and has written several books of poetry and drama.

Oxygen is part of what Djerassi calls 'science-in-theatre', which as explained in Chapter 1, refers to those plays with substantial scientific content and a pedagogical function. Djerassi writes: "What is wrong with learning something while being entertained? Or from the playwright's perspective, why not use drama to smuggle important information generally not available on the stage into the minds of a general public?" (Djerassi "Contemporary") This 'smuggling' of science in *Oxygen* has received positive comments from scientists,[40] but criticism from theatre scholars such as Shepherd-Barr and Suzanne Lynch for its "heavy-handed didacticism and lack of character development" (Shepherd-Barr 195). These critics implicitly portray these scientist-turned-playwrights as literary illiterates, and argue that the success of the play is not due to its literary merits; rather, it is due to the fact that it is written by two famous scientists who are very well-connected in the pharmaceutical industry: "It is the science rather than the drama of *Oxygen* that has attracted funding" (Lynch). However, despite criticism of the play's low quality as drama, *Oxygen*, as Lynch also rightfully points out, is an important play because "it suggests the ways in which the domains of humanities and science can overlap… it makes a bold attempt on the part of science to take its place in the world of the humanities – and to exploit the potential of theatre to bring scientific knowledge to a wider audience". This remark is as true of the play's ability to bridge the gap between the two cultures as it is of providing a more comprehensive from of education. The extraordinary success of *Oxygen* was followed by an increase in the tendency towards interdisciplinary approaches to education across Europe. After its premier in Germany in September 2001, Djerassi and Hoffmann's play was widely published for educational purposes. In the United Kingdom, 1,000 copies of

[40] Richard N. Zare, a professor in chemistry at Stanford University for Wiley-Vch; Jeffrey Kovac, chemistry professor at the University of Tennessee for the *Journal of Chemical Education*; Madeleine Jacobs, the president at American Chemistry Society for *Science and Technology*; Colin Martin, a science graduate from the University of Melbourne for the *Lancet*.

Oxygen were distributed in schools by the Royal Institution, and the play's London run targeted school groups with performances (Lynch). Regardless of the reasons for the fame of *Oxygen*, Djerassi and Hoffmann's play is one of the most important plays in the genre of the science play because it is science's attempt to bridge the gulf between the two cultures and therefore turn the stage to a place where Snow's vision of 'third culture' would be eventually realized. Moreover, since the play is written by two scientists, it places accurate and plausible science at the heart of the theatrical experience (Lynch).

Oxygen was written by two world-leading chemists who started from the opposite side, "using the stage for [their] scientific missionary aims", as opposed to "the professional playwrights… who mostly want to use science for their theatrical aims" ("Science-in-theatre"). "All the science and the behavior of the scientists described should be impeccably accurate or at least plausible" Djerassi says, because "I want to use science to smuggle scientific facts into the consciousness of a scientifically illiterate public – a pedagogic activity considered to be intellectually and socially beneficial because the majority of scientifically untrained persons are afraid of science" ("Science-in-theatre") – this gives us an idea of how prominent the role of science and scientists in the play is. *Oxygen* is all about chemistry and chemists, and the theatre is merely a container within which the content, a plausible and accurate depiction of real science and the behavior of its practitioners, is placed. In other words, as Zehelein explains, in *Oxygen* science becomes "the heart and soul" (77), without which the play could not have been written.

Oxygen is a play written by chemists, about chemistry, and presented by chemists. The play is full of detailed descriptions and discussions of chemistry embedded in the conversations that take place between renowned practitioners of the

field. Through these conversations, a detailed and clear description of the behavior of scientists, their motivations and ethical doctrines, is also provided. Due to the didactic and pedagogical purpose that *Oxygen*'s playwrights believe theatre serves, the scientific knowledge is simplified and clearly explained through the performance of a chemical experience. The chemists appear onstage performing the actual experiment of producing oxygen (Djerassi & Hoffmann 64-76), giving the audience the impression of sitting in a laboratory watching a group of chemists conducting and explaining a scientific experiment. Moreover, the complex scientific ideas are presented to the audience through a short masque performed in verse, which is in fact a mini-lecture that explains and illustrates the demolition of the theory of phlogiston by the theory of oxygen (42-45). The idea behind this simplification and clear conveyance of science and scientific behavior is to present it as well as possible, so that audiences are able to think about problems that they may not have thought about before, just because they feel they do not understand science ("Science-in-Theatre"). Even the historical aspect of the play, around which its dramatic focus is placed, deals with a crucial debate in the history of chemistry – who was the discoverer of oxygen? The two chemist-playwrights use this historical debate as an appropriate context within which to discuss the central theme of the play: what exactly is scientific discovery and what motivates it?

What Djerassi and Hoffmann do in the play is in fact teach the real science of chemistry by telling a theatrical story which has the real science of chemistry and its practitioners at the heart of it. However, Djerassi and Hoffmann do not use science metaphorically in *Oxygen*, meaning that the actions of the play do not reflect and mirror the science of chemistry. The playwrights' demonstration of science is not integral to the structure of the play and does not play an important thematic role. To illustrate and convey chemistry, Djerassi and Hoffmann rely heavily on textuality and direct

demonstration to serve their didactic purposes, rather than incorporating it into the dramatic action and eventually transforming it into a metaphor on the stage. Real science, in its most plausible and accurate form, lies at the heart of the play, but naked and very visible, rather than wrapped up in a cover of characters and their struggles that could only be analyzed with chemistry as a framework for analysis. Since the scientific idea that the play engages with, therefore, is not incorporated into the structure of the play and is not used metaphorically, the following discussion of the play within the framework of new physics is done without reference to chemistry.

The central theme of *Oxygen* is scientific discovery as demonstrated by the discovery of oxygen, told through two intertwining plots – similar to *An Experiment* and *After Darwin* – related to two different time periods: 1777 and 2001. To honor the 100th anniversary of the Nobel Prize, a committee of five has been asked to award the first 'Retro-Nobel' for a revolutionary scientific discovery that occurred prior to the origin of the prize in 1901. The committee's decision is to focus on the discovery of oxygen, the gas that launched the Chemical Revolution. But who should be honored? Scheele? Priestly? Or Lavoisier? Scheele was the first to discover oxygen but failed to publish his findings until 1777; Priestley discovered oxygen but still adhered rigidly to the theory of phlogiston, according to which "all flammable materials contain an odourless, colourless, weightless substance (phlogiston) that escapes upon burning" (Zare 1971) – yet he was the first to publish his findings, calling the gas "dephlogisticated air"; and finally Lavoisier, considered the father of modern chemistry, was the first to fully understand the nature of oxygen and to recognize that "combustion involved oxidation" (1971). As a result of his discovery the entirely wrong framework of phlogiston was demolished, but he was not the first to isolate the gas or identify its distinctive features.

In the 1777 plotline, the three candidates for the title of 'the Discoverer of Oxygen' and their wives are brought together in a fictional encounter in Stockholm at the invitation of the King of Sweden, Gustav III. The question to be answered: Who discovered oxygen? The device of alternating time periods is skillfully used to bring together the three claimants of the discovery of oxygen so that they will be able to legitimize their individual claims to priority, an issue being simultaneously investigated and argued by the Nobel committee in 2001. This is a technique also used in *Arcadia*. The chair of the committee is Astrid Rosenqvist, an excellent theoretical chemist and the first woman to chair a Nobel committee. Three other distinguished male chemists complete the committee: Bengt Hjalmarsson, Ulf Svanholm, and Sune Kallstenius. Each one of the contemporary scientists is given an eighteenth-century chemist to investigate. Over the course of their research, the audience is introduced to another central event that involves a letter Scheele wrote to Lavoisier in September 1774 in which he informed him of his discovery of fire-air and instructed him how to make it. The information that could have played a crucial part in Lavoisier's demolition of the phlogiston theory; but Lavoisier never acknowledged receiving the letter. The contemporary characters try to find out the letter's fate.

Oxygen revolves around the core question of what is discovery after all, embedding this question in the Nobel committee's struggle to define it: "Is it the initial discovery… the first publication… or full understanding?" (Djerassi & Hoffmann 109) Each member of the committee has their own definition of discovery, and struggles to make reality conform to their own agenda. However, the play ends without providing a certain answer as to what is the nature of discovery and who is the real discoverer, and the uncertainties surrounding these questions remain at the heart of the play.

In the course of the contemporary characters' investigations into the past, the ethical issues surrounding priority and discovery also gradually come to the surface in the play. The play features seven scientists – three in the past and four in the present – all dealing with the same issues of scientific ambition, competition, and priority, indicating that science has hardly changed in the last two centuries. They suggest that the ways in which scientists strive for priority and recognition are as timely today as they were in 1777, and contrary to the commonly-held but naïve notions that science is done for the science's sake and that discovery is simple, pure, and unaffected by claims to priority, it has, in fact, never been an untainted, idealist endeavor. This aspect of *Oxygen* connects it to *An Experiment* and *W;t* in that they all discuss a durable ethical violation at the heart of scientific research. However, in *An Experiment* and *W;t* the divorce of ethics from science is caused by the pursuit of sheer knowledge, while *Oxygen* demonstrates that contamination of the scientific endeavor can be due to fame and recognition being the motivations behind scientific research. The centrality of this characteristic of scientists in the play also likens it to *Secret Order*, *Remembering Miss Meitner*, and *Galileo Walking Among the Stars.*

However, the three eminent eighteenth-century scientists of the play are not, to use Zehelein's words, "the wheelers-and-dealers" (140) of the play; this role is taken by their wives. The world of *Oxygen* is clearly a woman's world. Over the course of the play, Rosenqvist introduces Ulla Zorn, an amanuensis who later on turns out to be writing her doctorate on the role of women in the history of science. She suggests to the committee that in order to properly select among the three candidates they need to dig into the lives of the women most closely associated with them, namely Mary Priestley, the wife of Joseph Priestley, Sara Margaretha Pohl, Scheele's longtime companion who married him three days prior to his death, and the nineteen-year-old Marie Pierrette

Lavoisier, who was not only his wife, but was also his assistant and amanuensis in the lab. These historical female characters, along with their twenty-first-century descendants, take matters into their own hands and alter the course of the history of chemistry.

The multidimensionality of *Oxygen* – gender roles, history, science, and ethics – and the significant role that time plays in the play make it possible to explore these chemists-turned-playwrights' work in the light of the implications of the new physics.

4.3.1 Nonlinear Time and Story

On Djerassi and Hoffmann's stage, time becomes a highly energetic character with double personality traits, one past and one present. Through the juxtaposition of a series of temporal oppositions that sometimes become an experience of unity, Djerassi and Hoffmann break the boundaries of Newtonian time and make the years 1777 and 2001 interact and overlap onstage.

The playwrights pursue the dual time periods of the play with authority and clarity. Similar to *After Darwin*, in some scenes, past and present are featured separately, while in others the two time periods are simultaneously onstage together. The framework of the play consists of twelve short scenes divided into two acts, four in the past (Scenes 1, 5, 6, and 9), four in the present (Scenes 2, 4, 10, and 11), and four in both time periods (Scenes 3, 7, 8, and 12). Scenes 1, 2, 4, 9, and 10 are followed by intermezzos set in the past with the exception of the one following Scene 4, which is set in the present. The intermezzos have little dramatic action and their whole interest lies in revealing the rivalry among the scientists of both time periods and the fact that they barely trust each other. Adding to the complexities of times displayed, the dual-time

scenes consist of twelve sub-scenes in which the natural time flow is suddenly interrupted either by introducing another time period (Scenes 3, 7, and 8) or another point in time within the same time period (Scene 5). Travel between the past and present happens on stage by having the same actors doubling characters from different periods, with the costume changes taking place before the audience's eyes.

As a result of *Oxygen*'s temporal discontinuity the audience is also confronted with spatial discontinuity. The play flows between a sauna, a royal theatre, and a bare room in Stockholm in 1777, to a conference room at the Royal Swedish Academy of Science in the same city but in another time period. In this sense, the stage becomes an area of illusion, which allows the audience not only to travel through time but also through space.

The play's Einsteinian treatment of time, however, means that the narratives of the play are simultaneously involved in a hectic game of hide-and-seek and a hurdling race. In the course of the play, the linear flow of information is constantly disturbed as a result of a continual change in the play's focus from the past to present, or vice versa. Audience members are watching the historical narrative smoothly and linearly unfolding on stage when a fragment from the contemporary narrative takes them to another time period, and therefore forces the historical narrative to pause until its turn to reappear. The same happens with the contemporary narrative. However, even the narrative linearity in one single time period is disturbed by the constant jumps that the narrative makes from one time frame, within itself, to another. This constant jump from one narrative and therefore one time period to another or from one time frame to another within a single narrative turns the play's narrative structure into a chaotic jumble of fragments that need to be detected, identified, and put in chronological linear order by the audience. During this mental energy-consuming process, the audience

follows the track of the narratives constantly jumping, disappearing, and reappearing, like a dramatic enactment of the way electrons move between energy levels.

Time in *Oxygen* moves in odd and unfamiliar ways. Finding justifications for this complex time scheme is not just a matter of theatrical technique; rather, the play's exploration of themes depends on it. Djerassi and Hoffmann present this temporality as the dissolution of the differences between past and present, to represent the contemporary characters as the 'double versions' of the historical ones; a group of scientists whose desire for fame and recognition is the common feature that connects them, despite distances. This aspect of the play can be discussed with relation to quantum entanglement.

4.3.2 Nonlocal Chemists, Nonlocal Motivations

Oxygen's double exposure of two different time periods amplifies what lies at the core of the play: the idea that priority, fame, and recognition have always been the driving forces of scientists. Djerassi and Hoffmann convey this message by drawing connections between past and present characters not only in terms of motives – featuring them as having the same motivations to do science regardless of their difference in time period – but also in terms of physicality – by having the same actors doubling between the time periods (a technique also used by Stephenson and Wertenbaker, as discussed above).

The science play practitioners establish similarity between past and present characters by means of a complex system of message exchange that instantly and constantly leads to the characters becoming entangled with each other, in what can be seen as a metaphorical depiction of the way in which particles make instant connections

across time and space. In a 2001 scene, for example, the contemporary scientists, who have been accusing each other of worrying about "missing out on prizes" (Djerassi & Hoffmann 17), wonder if the discoverers of oxygen "were as ambitious as their modern successors?" (18) Here, the concept of scientific recognition sends a signal to the past to become instantly connected with it, as a result of which the audience members are introduced to an intermezzo where the rivalry among the three historical chemists is revealed to them through their dialogues with their wives (19-21). Again, this past scene sends a signal to the present and instantly links with a scene in which the audience learns about the hostility between Svanholm and Kallstenius over priority in their scientific research. In a conversation between Svanholm and Hjalmarsson, it is revealed that a group of scientists at Stanford University published a very significant paper about new catalysts for oxygenated polymers, similar to Svanholm's paper that had been given to Kallstenius for review prior to their publication. But according to Svanholm, Kallstenius sat on the paper for two months before reviewing it, and made him waste another "half of the year getting another damned spectra he wanted" (23) – and in the meantime informed his friends at Stanford of Svanholm's findings. He accuses Kallstenius of using his power as a reviewer to allow his American friends to publish their results several months earlier and therefore to win the Gibbs Medal. This scene is followed by a blackout set in the past with the three chemists accusing each other of using the power and money of their patrons to influence the king in an effort to win a decision favorable to their interests as to who discovered oxygen (25).

This signal exchange between historical and contemporary periods is prominently reflected in Scene 8, in which Zorn questions the scientists' real motivations for doing science, both in the past and present:

> ULLA ZORN. When I see all of you… sniping at each other… worrying about who published first… who didn't…

> BENGT HJALMARSSON. You're puzzled.
> ULLA ZORN. This wasn't my idea of science and scientists.
> BENGT HJALMARSSON. You think we arrange beetles in a museum case?
> ULLA ZORN. I thought at the heart of science was sheer curiosity. I see that in Scheele… maybe also in Priestley. I start having troubles with Lavoisier. (66)

This present scene sends a signal to the past, and the audience is taken to 1777 where the three chemists are performing their experiments in front of the king, each claiming priority for the discovery of oxygen. During the experiment, the argument between the chemists gets so intense that the king becomes vexed and leaves (77). This scene shows that, despite what Zorn thinks, the three historical chemists are as much after recognition as their contemporary fellow scientists are. The time then returns to the present with Zorn and Hjalmarsson continuing their discussion about the scientists' real motivation behind their works (77-78).

Oxygen is full of these 'spooky actions at a distance' between the past and present. The present has the ability to instantaneously connect to the past and change its state by sending it a signal, even if they are separated by the large temporal distance of two hundred years, and the past can also do likewise. Djerassi and Hoffmann arrange their historical and contemporary scenes and sub-scenes in such a way that they portray both the past and present within the domain of scientific research as connected, and to depict the idea that scientists' thirst for priority and fame is as strong today as it was in 1777. The transfer of information between *Oxygen*'s scenes is an enactment in microcosm of the instant transfer of information from one particle to another even from opposite sides of the universe.

To intensify the connection and similarity between the historical and contemporary chemists, the playwrights use the technique of having the same actors doubling the roles. The actors who play Hjalmarsson, Kallstenius, and Svanholm in turn play Lavoisier, Priestley, and Scheele, respectively. Having the same actor playing the

role of a chemist in the eighteenth-century with priority and recognition as the driving forces behind the practice of science, and another chemist in the twenty-first-century operating on exactly the same motives, reinforces the suggestion that the contemporary scientists are in fact unchanged versions of the historical scientists, who after two hundred years have been able to change the world with their science but have not been able to change themselves.

4.3.3 Compatible Incompatibilities

Bohr's complementarity principle can be discussed with relation to the two main confrontations that permeate *Oxygen* and make up the building blocks of the play: male-female and chemistry-history. These confrontations eventually resolve into a single unified entity to serve the purposes of science. The former is illustrated through the emphasis that Djerassi and Hoffmann put on the role women have played in the history of science; when the committee members look for clues as to how to begin their investigation into the past, Zorn suggests, "Most men around that time had wives. Why not look for what they had to say?" (18) The audience then sees the historical chemists consulting their wives about issues related to their scientific discoveries. They see Priestly talking to his wife about how to prove his priority (56-58), Scheele discussing with Fru Pohl the letter he wrote to Lavoisier (47-49), and Lavoisier and his wife having a conversation about how to manage his rivals (19, 84). Even the action begins with women: the play opens with a scene in a sauna where the conversation between the scientists' wives fully introduces the audience to the rivalry between their husbands to be recognized as the discoverer of oxygen, and the theme of the play. Madam Lavoisier proposes "the quest for reputation" as the major concept that characterizes the scientists:

"My husband told me something very useful. The product of science is knowledge… but the product of scientists is reputation" (5) Fru Pohl also mentions Scheele's 1774 letter to Lavoisier, which forms one of the key elements of the play. Throughout this scene, the audience realizes that the rivalry between the historical chemists also exists between their wives, who consider their husbands' work to be their own. The role of their wives in the chemists' scientific discoveries is further underlined when Hjalmarsson suggests that to find out who the true discoverer of oxygen is they should search for "dirt", referring to the work of experimental chemists that "get their hands dirty" (32) in the lab working with chemical substances. Zorn then suggests consulting the wives, as usually they are the ones expected to clean up this dirt (32). Through this image Djerassi and Hoffmann indirectly refer to the role of women in their husband's scientific achievements, backing up their claim by providing evidence later in the play. In Scene 7, for example, Scheele makes a discovery simply by touching a part of Fru Pohl's body: "Scheele: *(*[…] *takes her* [Fru Pohl's] *hand, pauses to inspect his and then hers)* Look! The coffee sticking to your hand! Is it some form of magnetism?" (49) Madam Lavoisier helps her husband not only in the laboratory but also in the salon (9): "Each day in the laboratory, I made a list of what experiments were to be done. Antoine called out the numbers. I wrote them down. I drew the plates for his books… I etched them… I corrected them" (6). She completely identifies with her husband and his work and uses 'we' instead of the singular form:

> MRS. PRIESTLEY. What do you mean?
> MME. LAVOISIER. We are not convinced –
> MRS. PRIESTLEY. We?
> MME. LAVOISIER. My husband is not convinced… and therefore, I am not convinced. (6)

The wives' contribution to their husbands' discoveries is most skillfully illustrated in Scene 8, when the three historical scientists' experiments in the presence

of the king is constantly interrupted by their wives' conversation in the sauna, discussing exactly the same procedures and techniques their husbands are using to achieve their results. This embedded sauna sub-scene clearly shows that "these three women were much more than bystanders to the scientific accomplishments of their male partners" (Zare 1972).

Nevertheless, the pivotal role of Madam Lavoisier in the action of the play is what truly shows that it is through the partnership between men and women that scientific discoveries are made. Madam Lavoisier is a clever, mathematically able woman who strives to enter the male-dominated realm of science and complains that, despite her vital role in her husband's scientific achievements, she is not being recognized and appreciated as an equal partner: "When he reasoned out how we breathe… how sulfur burns… how to make better gunpowder… he spoke to men… But not to me" (Djerassi & Hoffmann 9). Drawn into the maelstrom of priority, fame, and recognition at all cost, she thus takes matters into her own hands and bends the course of the history of chemistry. She decides to hide the letter that Scheele wrote to her husband and instead use its contents in the laboratory to assist him so that he can be the one to discover oxygen first, and take all the credit and fame for it. In doing so, she guarantees herself a vital role not only in her husband's scientific achievements but also in the discovery of oxygen. By deciding to hide the letter she bends the course of history by adding an element of uncertainty to it: did Lavoisier receive the letter? Did he borrow from his rival's experiments? Madam Lavoisier's scientific endeavors finally pay off when future generations recognize her active part in Lavoisier's work; Rosenqvist says that "We all know what role women played in chemistry at that time. Madame Lavoisier got about as close as was realistic" (114).

Djerassi and Hoffmann also allow the other female historical characters to have their ambitions and potential realized by others. They use the same technique of 'one actor, two roles' for Mrs. Priestley and Rosenqvist, and for Fru Pohl and Zorn. By having the same actors playing the ambitious eighteenth-century women, whose freedom to achieve their potential was denied in the male-dominated society of the time, and the successful twenty-first-century chairwoman and talented historian, the playwrights suggest that Rosenqvist and Zorn are in fact evolved versions of the historical women. Through the medium of the same body, the talented eighteenth-century women are brought back to life in the guise of two successful and intelligent women, able to finally put their talents and potentials to use and add some estrogen to a world dominated by testosterone. Djerassi and Hoffmann's eighteen-century female characters, therefore, similar to Stephenson's historical women, evolve into more intelligent and successful contemporary versions of themselves.

The fact that *Oxygen* is a woman's world rather than a man's world is made clear in Madam Lavoisier's remarks to the audience in the first intermezzo: "So… we talk women's talk. About our husbands, of course… Wearing the woman's mask… her husband's face on it… smiling politely" (9). The pivotal role that women occupy in Djerassi and Hoffmann's play produces a world of pluralities and dualities in which men and women are two opposite halves who must unite, cooperate, and form themselves into a single unified whole: that is, scientific discovery. In other words, what the playwrights are trying to say is that at the heart of scientific discovery there is a union of two opposites: men and women. This aspect of the play connects it to *Comet Hunter*, *Remembering Miss Meitner*, and *The Talking Cure*, in which two contradictions, women and men, behave as the two opposing descriptions of particles and unite and become one in the form of a single entity.

The double confrontation of the two seemingly contradictory domains of history (as a field in the humanities) and chemistry (as a scientific field) is illustrated through the only historian in the play, Ulla Zorn. The male members of the committee disparage history and historians:

> ASTRID ROSENQVIST. What's wrong with historians?
> SUNE KALLSTENIUS. It's a thing scientists do when they can't do science anymore.
> ASTRID ROSENQVIST. But professional historians?
> BENGT HJALMARSSON. What would they know about science? (*Pause*) You might as well search the web! (16-17)

The chemists' attitude towards history reveals both a patronizing view and a deep gap between the hard and soft sciences that characterizes today's academic circles. However, over the course of the play, the scientists are forced to "swap the laboratory for the library" as Lynch explains, in order to dig into the past and elucidate the historical facts about the discovery of oxygen. In other words, in order to find out who the true discoverer of oxygen is, they are required to turn the pages of history, one by one, in search of plausible, accurate evidence.

Moreover, it is Ulla Zorn, the only historian on the committee, who finally uncovers the secrets of the play and succeeds in revealing one of the long-buried truths in the domain of chemistry. After a quick flight to Cornell University and a search of their collection of the Lavoisier papers, Zorn finds Madam Lavoisier's book-like travel chest (95). The secret of the play is uncovered when Zorn reveals the secret of the travel chest. Underneath the tray there is place for stationary and right above it, in the lid of the box, there is a broken mirror with a space behind it. Inside the space, there is a letter: a letter Madam Lavoisier wrote to her husband nineteen years after Scheele's letter, in which she explains the reasons why she withheld it: "I ask you now to forgive me. I could not show Apothecary Scheele's letter to you, my dear husband. It would have taken the wind out of your sails, you, who were so close… And I told you why I

felt incapable of destroying it. Our priority rested on my hiding it" (99). As a result of Zorn's discovery, the mystery of Scheele's 1774 letter, which has been baffling chemists for over two hundred years, is finally solved. Women again changed the history of chemistry: one created a mystery and one resolved it. Djerassi and Hoffmann's decision to have a historian, not a scientist, unveil one of the most important secrets in chemistry, and the fact that the scientists eventually turn into historians in the course of their scientific research, underline the playwrights' attempt to fill in the gaps between the two cultures. Once more, it is demonstrated that it is as a result of the union of opposites, this time the humanities and the sciences, that scientific discovery can occur. The playwrights' attempts to realize Snow's vision of a third culture establishes a metaphorical parallel between their play and Bohr's particles, whose existence is defined as the union of opposites. But is the chemists-turned-historians' attempt to identify the true discoverer of oxygen fruitful? Djerassi and Hoffmann prefer to let the audience answer this question.

4.3.4 Who Is the Discoverer?

Despite all the detective-like efforts of the Nobel Committee, the play provides no answer to the question of who discovered oxygen, since it is open-ended. The contemporary scientists conclude: Scheele discovered it first; Priestley published first; and Lavoisier understood it first. Who then should be honored? The four members of the committee take four different views, with Rosenqvist choosing all three and the others each choosing a different man. They eventually decide to vote for a pair. Hjalmarsoon and Rosenqvist's first candidate is Lavoisier, but we are not told who their second candidate will be. To keep Lavoisier from getting the prize, Kallstenius and

Svanholm decide to vote for both Scheele and Priestly. Each of the characters therefore uses their own personal observation of the evidence or their own preferences as the basis for selection. In other words, their subjective observation determines who the discoverer was. Djerassi and Hoffmann decide not to reveal the very final decision of the committee. This may be because there is no final decision, amidst a series of conflicting views stemming from subjective observations, or it may be because this open-endedness corresponds to what Djeraasi considers as the most valuable purpose of 'science-in-theatre': to help audience members understand the science so that they are in a position to ask intelligent questions regarding the scientific ethics:

> These are all gray issues. There are no black and white answers. And there is the question I really would like to ask the spectators to ask themselves. And the answers, in my opinion, cannot be provided by scientists, cannot even be provided by governments. I think the answer can be provided by individuals, based on reasonable information. And one of the attempts – perhaps the main attempt – of my play, aside from amusing you, is to actually inform you so that you are better informed to make complicated decisions about enormously complicated and ethically charged problems. (Djerassi, qtd. in Kauffman)

This is why he and his co-writer decide not to restrict the possibilities to a binary choice, but rather to offer the audience a variety of prospects. In Djerassi's words, "There are seven alternatives for our Retro-Nobel: it could be awarded to the three people individually, three pairs, or all three together" (qtd. in Devins 24). Regardless of the intention behind the open-endedness of the play, the emphasis that the playwrights place on the role of personal opinions and observations on the formation of the uncertainties surrounding the discovery of oxygen, can once again be interpreted as a figurative representation of two principles in quantum mechanics: the observer effect and uncertainty.

Oxygen as a science play in the category of 'science as leading character' places science at its center by providing not only a detailed and accurate description of chemistry, but also by directly performing chemical experiments to produce oxygen on

stage. Djerassi and Hoffmann even go further by placing the focus of the play on one of the most controversial incidents (the discovery of oxygen), in the history of chemistry. Djerassi and Hoffmann break free from the limitations of Newtonian time and space by creating a network of interconnected historical and contemporary scenes and sub-scenes that belong to both past and present. Throughout the play, the past and present constantly flow in and out of each other and create an episodic narrative structure that unfolds on stage in the same fashion as the movement of electrons inside an atom: jumpy and nonlinear. The complex process of message exchange that governs the arrangement of the historical and contemporary scenes and the technique of 'one actor, two roles' instantly bridges the vast spatial and temporal distances between events and characters. This instant connection suggests the complex information transfer from one particle to another at the subatomic level. The relationship that *Oxygen* establishes between two opposite pairs, men and women and history and chemistry, and its attempt to form them into unified entities, can be read as a metaphorical application of Bohr's complementary principle. The play's refusal to provide a definite answer to who the true discoverer of oxygen is, due to giving equal validity to different interpretations presented by different characters, can be seen as a reflection on the uncertainty principle and the observer effect, and their effect on meaning.

This chapter showed us how the form and content in text-based science plays can convey scientific ideas. The following chapter will take us to the realm of performance, and shows how science can be presented and conveyed within a performative paradigm.

Chapter 5

Science as Director

5.1 Introduction

In Chapters 3 and 4, the intersection between post-quantum reality and contemporary science plays was investigated with reference to four text-based science plays that were analyzed within the context of the new physics paradigm. In this chapter, two performance-based science plays by the theatre company Complicite are examined in order to show how dramaturgical techniques and theatrical strategies can be used to convey scientific ideas on stage.

Complicite is widely recognized as one of the most innovative and influential physical theatre companies in the United Kingdom. It has created more than 35 productions and received more than 25 major international awards since it was founded in 1983 by four creative artists: Annabel Arden, Simon McBurney, Marcello Magni, and Fiona Gordon. Complicite's dramaturgical strategies of innovative multi-media designs and theatrical techniques, physical theatre choreography, and total-theatre techniques combining projections, sound effects (live and pre-recorded), music, dance, and physical movement generate a model of playing that encourages audiences to engage with complexity in the theatrical event. This quality enables the company to explore the metaphorical and theatrical potential of complex scientific discourse in their plays. *Mnemonic* and *A Disappearing Number* are two science plays that employ the above-mentioned theatrical techniques to enact scientific ideas, attempting to render the complex neuronal and psychic mechanism of memory (*Mnemonic*) and the difficult discourse of abstract mathematics (*A Disappearing Number*) within a performative

paradigm. In these plays the audience's understanding of realistic science is facilitated through direct presentation of science (in the form of scientific lectures), as well as its employment as an extended theatrical metaphor.

In Complicite's science plays there is no monolithic, authoritative, and fixed central text; rather, the dramatic material is created through a lengthy process of improvisation to which the actors and artists directly contribute. These plays therefore rely less on textuality to convey ideas than on the visual and physical experience of the audience. Neuroscience and mathematics are explored in the plays through the company's trademark approach that depends on "the expressive powers of the body and the transforming capacity of inanimate objects" (Taylor). This emphasis on physicality and the imaginative transformation of props rather than direct explanations presented in the form of dialogues calls for a high degree of involvement on the side of the audience, and directly engages them with the scientific material. The interactive exercises the company performs in the plays also reinforce this engagement. As a result, audiences come into direct contact with real science and are immersed in the ideas theatrically. In other words, "the experience of the audience becomes much more about imbedding, sensing… the science through its enactment than about listening to explanations of it from characters" (Shepherd-Barr 201). It is therefore the theatrical experience that conveys the scientific content, with the audience participating in the act of conveyance. The science, in other words, becomes both the content and the form with which it is conveyed. Complicite puts real historical characters and events – the collaboration between two renowned mathematicians (*A Disappearing Number*) and the discovery of a 5,000-year-old body in the Alps (*Mnemonic*) – along with real science at the heart of the plays and introduces its audience to a world whose every aspect has been penetrated by science. As the following discussion will show, the dramaturgical and theatrical

techniques that Complicite employs to convey science in these plays provide an appropriate context within which to discuss new physics.

5.2 The Expression of Origin: Staging the Imaginative Act of Remembrance in Complicite's *Mnemonic*

Mnemonics are memory devices that help us remember. They are tricks that aid our memories in remembering something that is otherwise quite difficult to recall. The rhyme '*I* before *e* except after *c* or when sounded like *a* as in *neighbor* and *weigh*' helps us remember how to spell words that contain *ie* or *ei*. In physics classes, teachers help students remember the colors of the spectrum by giving them the acronym 'Roy G. Biv', standing for red, orange, yellow, green, blue, indigo, and violet. As would be expected, Complicite's play *Mnemonic* is about memory. First devised and produced in Salzburg in 1999 and then toured all around Europe, the play tackles the challenging question of how to depict the act of remembrance. Complicite's work attempts to present memory in its full complexity, and asks us how we can go beyond our personal reminiscences to travel across the domain of our collective past. The title of the play refers to large-scale mnemonics, devices that remind us of things "across personal histories, cultures, epochs, geographies, and generations" (Shepherd-Barr 144).

Mnemonic opens with a lecture about the biochemistry of memory delivered by its director, Simon McBurney. "Modern theories of memory", he points out, "revolve around the idea of fragmentation" (Complicite, *Mnemonic* 3). Different elements of a memory are stored in different parts of the brain and once it is triggered by a mnemonic, it begins to sprout madly, drawing connections between its fragments to create a pattern, a map of connections. This is not a neat, stable, "ordnance-survey" map but one that is

"constantly changing and developing. Each time we read the map, thousands of roads have been added and all the contours have shifted… [I]t's chaos in there. It's constantly changing". The job of remembering is therefore "to reassemble, to literally re-member, put the relevant members back together". However, McBurney concludes, "re-membering is essentially not only an act of retrieval, but a creative thing, it happens in the moment, it's an act, an act… of the imagination" (4).

Complicite builds the foundations of its play on something that is nothing short of a contemporary obsession. A preoccupation with memory seems to stand at the heart of our society. "In a society fascinated with psychoanalysis", Freshwater argues, "we have accepted that past experience produces identity, and are accustomed to drawing sets of causal links between our personal history and our sense of self. This awareness of the past, and the valorisation of our recollection of it, is part of our everyday language, the texture of contemporary culture, and an ideological *a priori*" (213). *Mnemonic*'s exploration of the neuronal and psychic mechanisms of memory should be defined within a larger context, that of our collective past and the significant role it plays in the formation of our identities. The play depicts our sense of self as heavily wrapped up in a thick cloak of our common recollections of the past. It uses memory as a device by which characters move beyond their individual identities, defined within the boundaries of specific timeframes, geographical locations, nationalities, and cultures, to discover their common origin.

In his lecture on memory, McBurney asks audience members to perform a certain act that enables them to recollect specific moments of their past and ultimately visualize their common ancestral origins: they are instructed to cover their eyes with an eyeshade and while feeling the patterns on a leaf (taped to the back of their seats along with the eyeshades) to remember what they have been doing at different stages of their lives.

They are then asked to imagine that they are five years old holding the hand of their mother in one hand and the hand of their father in another, with their grandparents standing behind them. McBurney takes this family linkage further back in time, suggesting that our mutual ancestry is as complex and interconnected as the veins on the leaf:

> Imagine that each vein is a line of your ancestry all coming down to you, the stalk. All of them leading to you. In one hundred years there are four generations. If you look back along the line behind you, as you look back, at the beginning of the nineteenth century standing in that line are 256 of your relatives. At the beginning of the eighteenth century, assuming there are no kinship ties, there is a line of 4,064. At the beginning of the seventeenth century there are 64,000 and in the sixteenth 1.5 million. And a thousand years ago that line would be longer than all people who have ever been born. Which, of course, is not possible… but it means that you are related to everyone sitting in this theatre. (Complicite, *Mnemonic* 7)

McBurney creates a utopian sense of connection, suggesting that human history and identity are common and continuous. At this point the audience is taken seamlessly from the real into the fictional: in a sustained blackout, McBurney's live speech gradually turns into recorded speech. The lights come up and McBurney is revealed to have changed into the fictional character Virgil, sitting in a theatre listening to McBurney's recorded lecture. At this point, the audience dives into a series of quest narratives, all concerned with identity, constantly flowing in and out of each other.

The backbone of the play is the fictional story of a contemporary couple, Virgil and Alice. After her mother's death, Alice discovers that her father, who she thought was dead, might still be alive, and embarks on a journey across Europe in search of him. Virgil, who is haunted by the sudden disappearance of his girlfriend, is desperately looking for an explanation as to why she left. Covering his eyes with an eyeshade and being instructed to go back in time to remember/imagine his personal and collective histories, Virgil's train of memories is set in motion, taking him through a journey into his last days with Alice and the 1991 discovery in the Austro-Italian Alps of the

Iceman's body from 5,000 years ago, a period which roughly corresponds to recorded history. The leaf and the eyeshades act as mnemonic devices that trigger the recall of his memories and therefore turn the play into a process of recollection happening within the proscenium arch frame of Virgil's memories. For the first half of the play, he only recalls memories of Alice and the Iceman's story, which he narrates and occasionally enacts for the audience by taking the role of the Iceman. Through him, we follow scientists and archaeologists experimenting with and analyzing the Iceman's body and belongings in order to reconstruct the details of his everyday life during the Neolithic period. In the second half of the play, Alice finally phones Virgil and her story is told through these phone calls. While she recounts the story of her journey, Virgil's memories of the Iceman begin to alternate with the fragments of Alice's story. While a story of flight and violence is gradually formed around the Iceman, the audience follows Alice during her journey across Europe, narrating and enacting more recent stories of exile experienced by the immigrants and refugees she has encountered: those of Simonides, a Greek taxi-driver who has been travelling throughout Europe in search of a better life; a British Jewish BBC reporter; Alice's Polish father with Jewish origins; a German maid with a daughter and a husband who suddenly disappeared; and a group of Jewish American tourists on a cultural pilgrimage around Europe. All these narratives are linked by images of displacement, forced immigration, and banishment. Within the territory of Virgil's memory, all these characters come alive and have their stories enacted in front of an audience with whom they share the same roots and origins.

With most of the play taking place within the territory of memory, the same rules of fragmentation and episodic structure that are applied in the process of remembering are applied to *Mnemonic*. Complicite's play is filled with mnemonic devices that direct the train of Virgil's thoughts. At each stop along the way, a different time frame,

location, and set of characters and events are presented. The territory of the play, therefore, similar to the territory of memory, is nonlinear and chaotic, full of temporal and spatial fluctuations. With only a minimalist set – a table, chairs, a bed, a rock – the play moves freely between different points in time and space. The actors have to use the play's simple and limited props to create a train, a mountain, a graveyard, a laboratory, and a press conference; a wooden chair is once a train, once a café, once a mountain, and once a human body; a wooden table is one minute a laboratory table, next a mountaintop being ascended by mountaineers (Appendix 1, Fig. 2), and then a conference table; a simple rock becomes a mountain when characters lie on it and becomes a grave when they stand before it praying. This multifunctionality of simple props, together with the skillful use of video projections, sound effects, and voice-overs, enable Complicite to instantly travel through 5,000 years of time across mainland Europe. The shift in time and space occurs after sound-effects of "ear-splitting" (Complicite, *Mnemonic* 20) and "terrible" (24) winds, and the projection of images such as trains or laboratories on the screens, facilitating the transition from one time/space frame to another. A plastic curtain drawn across the front of the set, with actors performing behind it, is a skillful dramaturgical device enabling Complicite to separate the presentational space from the fictional one (Appendix 1, Fig. 3).

In order to reproduce the discontinuous nature of episodic memory, Complicite resorts to blackouts. The best example occurs in Scene 2, in which Virgil has turned on his answer machine and listens to the message Alice left before her disappearance: "You have to wait now and this time you follow me" (15). Unable to sleep, he then immerses himself in a series of memories of her. This process of remembrance is illustrated by a sequence of short blackouts one after another while Alice's answerphone message is played repeatedly.

Due to the fragmented nature of *Mnemonic*, the reciprocal association between its elements – narrative lines, characters, events, props, spaces – is not immediately evident. However, Complicite uses the device of repetition to ensure the audience's recognition of the play's pattern of interconnectedness. *Mnemonic* contains actions that are either re-enacted multiple times (39-40) or are repeated in the form of flashbacks (74). There are key sentences that different characters repeat throughout the play either as voice-overs or live or in a series of entwined dialogues (75).

Mnemonic refuses to form any neat narrative closure, indicating that a definitive retrieval of the past is impossible due to the subjective and unstable components of memory. However, in its exploration and enactment of the act of remembrance, the play provides such a precise metaphorical paradigm that the workings of memory are explained in the clearest and most beautiful fashion. The following discussion will clarify the point further and shows how the exploration of memory can create a universe that can be defined within the boundaries of new physics.

5.2.1 When? Where? How? I Can't Remember!

In *Mnemonic*, similar to *W;t*, the device of memory helps the characters to fracture the illusion of Newtonian absolute time and space and generates instead, a sense of temporal/spatial relativity. Using as a structural device the complex system of stimulation and connection on which the act of remembrance is based, *Mnemonic* creates a narrative structure that is similar to the way particles constantly jump from one state to another in the orbit of the play. Complicite creates a narrative pattern that mimics the fractal structure of memory and its impossibly complex interconnections. The play's main narrative (Virgil's) contains the fragments of seven mini-narratives,

each located in a different spatial dimension: the fragments of Alice's narrative take place in six countries (Britain, Germany, Poland, Latvia, Ukraine, and Italy); the narrative fragments of Alice's father fluctuate between Poland, Latvia, and Ukraine; the fragments of Simonides' narrative travel from Britain to Greece and vice versa; the Iceman's narrative fragments are set in Austria and Italy; the maid's story happens in Germany; and the BBC reporter and American tourists' narratives take place somewhere in Europe. The temporal scope within which these fragments operate covers three years: 1991, 1998, and 1999. Within the framework of Virgil's memory, the time/place frame of the main narrative is capable of stretching across Europe and covering the temporal scope of all the mini-narratives while his body is trapped in a small flat in London in 1999. As the mini-narrative fragments move between different times and places, they follow each other in rapid succession without apparently rendering any connection.

Each mini-narrative releases its fragments through and across the spaces of other mini-narratives so that it develops in an episodic and fractal fashion. As a result, each mini-narrative is in a continuous process of 'leap-frogging', due to its flow being constantly interrupted by the emergence of the fragments of its fellow mini-narratives. This makes the main narrative a chaotic jumble of disjointed fragments scattered across the play's time/space spectrum that needs to be disentangled by audience members to obtain a linear pattern. They therefore have to be in a constant process of fragment hunting and pattern making to create linear narrative lines, a chronological time frame, and an ordered spatial map. The episodic pattern of the development of the mini-narratives also makes the main narrative unfold in a fractal nonlinear manner, adding another level of complexity to the play's process of story delivery. However, as the mini-narratives instantly divide and combine in a chaotic fashion, the play reveals a

pattern of connections that explains the temporal/spatial fluctuations and the episodic narrative structure. The audience gradually realizes that the arrangement of the fragments is determined by a complex process of stimulation and connection. One fragment in a different narrative context and time/space dimension appears onstage and releases a word that immediately stimulates Virgil's memory to set its train of associations in motion, and takes the audience to another moment in time and another location in space to show them another set of characters within the boundaries of another narrative line. In doing so, the seemingly disjointed and discrete narrative fragments link with each other and form a string of worry beads, as it were, the connecting thread of which is a direct imitation of the mechanism of memory: a fragment appears, releases a mnemonic device, stimulates the memory to begin connecting with another fragment, and disappears to make way for it. This aspect of the play also imitates the transfer of information from one particle to another that will be explained shortly.

At the beginning of the play, McBurney clarifies how a chair, as a mnemonic device, can become the cause of a complex connection between random things in his brain. He explains that the chair that is on the stage reminds him of his father (who sat on it), his grandfather (to whom it belonged), and the history of his company (who used it in their production of Ionesco's *The Chairs* (1997)). The chair, in fact, sets off a series of electrical reactions that order his brain to sprout more connections and remember different events. This is how McBurney prepares the audience for what is to come: a complex game of pattern making by means of mnemonic devices that are constantly released during the play. The nonlinear episodic narrative structure and the chaotic time/space map of Virgil's account of the past are due to the mnemonic devices that constantly appear in his memories and stimulate his brain to connect with more events.

This complex process can be explained more clearly with reference to the play.

The word ‘weather’ is the mnemonic device that begins the process of Virgil’s memory association. In his lecture, McBurney uses weather as a metaphor to describe the unpredictable and ever-changing nature of memory: memory “is constantly changing. We don’t have any idea of why, when or how it is going to change we only know that it will. It’s like the weather; completely unpredictable” (Complicite, *Mnemonic* 4). Here, in Virgil’s head, who is in the audience listening to the lecture, weather is associated with chaos and instability. Later in the play, he uses the same metaphor to describe Alice’s chaotic inner state in a phone conversation with his friend: “And I suddenly realized what’s happening to her… It’s feedback, turbulence, her internal state is like the weather” (15). Now weather, in Virgil’s head, is associated with both Alice and chaos. This word puts the first log in the firebox of Virgil’s memory train to begin its journey into his near past (his last memories of Alice) and distanced past (the 1991 discovery of the Iceman); right after the phone conversation, Virgil is reminded of “the chaotic movement of the weather” that caused “a high-level southerly air current between the fifth and eighth of March 1991 to transport a Saharan dust cloud… over a wide area of the Austrian Alps” (16), which eventually accelerated the disappearance of the snow and therefore revealed the body of the Iceman sticking out of the ice. The audience then sees, in an enactment of Virgil’s memory/imagination, the discovery of the Iceman’s body by two mountaineers. Right after this short trip to the Alps in 1991, the train stops in a station in 1998, where the audience sees Virgil remembering his last answerphone message to Alice and imagining her sitting in a Eurostar train listening to it and then immediately erasing it.

The word ‘funeral’ is another important mnemonic device in the play. In Scene 7, the police officers’ attempts to pull out the Iceman’s body fails due to bad ‘weather’.

The mnemonic impact of weather causes Virgil again to remember his answerphone message for Alice. In this message, he complains about her leaving after her mother's funeral without any explanation. The word 'funeral' stimulates Virgil's memory to connect a series of funeral-related events, each associated with a different narrative and a different time/space frame. He first remembers a conversation with Alice about funeral practices of different cultures in their flat in London before her disappearance. This scene gives way to another scene in which Simonides and his mother are in a graveyard in Greece attending his father's funeral. Here he decides to embark on a journey around the world in search of a better life. The next two scenes show the archaeologists in Austria in 1991 explaining their archaeological findings concerning the Iceman's body and the fact that he had "a cold and lonely death. As if nature was scoffing at a puny human, depriving him of a normal burial" (27).

Mnemonic is also full of individual mnemonic devices that are suddenly released in the play and begin a chain of random narrative fragments that are connected with each other, rather than with a mutual concept or word. Scene 21 begins with Alice in a hotel room in Germany in 1998. A maid enters her room and, while making the bed, finds her father's watch, drops it on the floor, and breaks it. The audience then immediately sees Alice in a taxi in London where she meets Simonides for the first time. Her father's watch is broken and Simonides offers to fix it. She then asks him where he is originally from, to which he replies, "Greece" (44). The word 'originally' takes Virgil to another time and space, reminding him of McBurney's lecture where he refers to his encounter with a Greek taxi driver, asking him exactly the same question about his origins. The audience then sees Virgil, now as McBurney, taking Alice's place in the taxi. The next scene cuts back to the hotel room where the same conversation about origins takes place between Alice and the maid. Alice is explaining to her that the

watch she broke belonged to her father, when the audience is immediately back in Simonides' taxi where he tells Alice that the worry beads he is holding belonged to his father and to his grandfather before him. Here, the word 'father' becomes the mnemonic device. Simonides then shows Alice a picture of his little boy who "looks like his mother but only the face because inside he's like me" (46). The mnemonic effect of this sentence causes the scene to instantly go back to the hotel room where the maid says that her daughter's face looks just like her father but "she is completely different inside, she's like me". She then asks Alice to forget the past because "in the past, you always arrive too late. Too late. Don't go back, go home" (46). The audience then travels back in time to Austria in 1991 where the archaeologists are analyzing the Iceman's body and objects in order to reconstruct the details of his past life through forensic analysis.

Mnemonic's narrative imitation of the episodic and non-chronological structure of memory is a reflection of the ideas of relativity theory and the quantum leap. This can also be interpreted as a figurative enactment of the process of entanglement, as it enables characters and events to overcome the limitations of time and space and to instantly connect with each other, despite the temporal and spatial distances between them. The following section will clarify this intersection between the play and new physics further.

5.2.2 Ascendant/Descendent Entanglement

One of the ways by which Complicite creates instant connections between distanced events is a complex process of message exchange. As explained in the previous section, words, functioning as mnemonic devices, become the connecting force between seemingly random events. The event being enacted onstage releases a

mnemonic trigger that brings another event, in another time/space frame, into the memory and therefore onto the stage. That is to say, the word becomes a message communicated between the two events, immediately linking them with each other. As a result of this complex process, long temporal and spatial distances are instantly traversed, creating a complex web of distanced events with hidden connections and correlations. Complcite's attempt to model *Mnemonic*'s succession of events according to the workings of memory creates a quantum universe in which signals travel between vastly distanced quantum systems getting them instantly entangled.

But the distances of the play are not travelled only through creating immediate connections between events. The similarities that Complicite draws between different characters in different time/space frames also make the instantaneous correlation possible. Once the similarities are established, the characters become permanently entangled, creating a network of connections in which one element cannot exist independently from other elements. People whose lives have been, in one way or another, defined or affected by the past populate *Mnemonic*: Alice follows her father across Europe, from west to east, in search of her unknown past; Virgil obsessively replays his last memories with Alice in an attempt to find an answer for her sudden disappearance; the body of the Iceman becomes an ancient national monument, a precious symbol of the connection with the past; and the American tourists travel around Europe to follow the trail of their Jewish ancestry. Alice's father, herself, the Americans, and the BBC reporter are heirs of a particular history and culture that defines their present: Judaism. They are parts of a historical network of conflict and grief that is characterized by migration and exile. They are receptacles of a certain heritage that has made them citizens of the world: similar to the people trapped in Wertenbaker's world after Darwin, Complicite's characters are also people with a

collage of identities with no place to which they can develop a sense of belonging. They are full-time professional migrants who are doomed to travel for the rest of their lives due to the "five thousand years of… struggle, migration, and stories" they have to carry within themselves, as the BBC reporter says (52). A Polish father, a Welsh Lithuanian daughter from north London with a half-brother in Ukraine, a British BBC reporter with four grandparents all born in different countries, and a group of Americans who "have moved dozens of times in their lives" (48) are all connected with each other through their Jewish historical and cultural bonds and what they have to endure as a result.

This sense of displacement also connects Simonides and McBurney to these global citizens. The Greek taxi driver cannot develop any sense of belonging to any place and is "always running from east to west. Always running from other fucking people" (54). He is a taxi-driver, originally from Greece, who worked in a watch factory in Germany, moved to England to start a family, and is planning to emigrate again to Melbourne and after that California, until he dies, to eventually wake up in a better life. Similar to the Jewish characters in the play, he also carries a history of running and struggling to survive. His grandparents were Greek refugees from Turkey who during the Greco-Turkish war had to flee to save their lives. McBurney himself is also a sort of global citizen: he is a British theatre director from an American father and a part Welsh, part Scottish, part Irish, part English mother. This similarity and connection between characters is further underlined by similar corporeal attitudes that the actors adapt on the stage (19, 39, 41, 54) and the traditional songs that they sing together (24, 54).

In this respect, Alice's journey around Europe in search of her father – as one of the heirs of this culture of displacement – can be interpreted, to use Casado-Gual's words, as "representing the search for identity, which entails an understanding of one's origins" (184). The Americans' cultural pilgrimage around Europe is of the same

nature. However, contrary to Alice and the Americans, Simonides and the German maid favor forgetfulness as a mechanism to "succeed on a prosperous blank state" (184). They prefer not to look back as they are interested in what lies ahead; they are the pilgrims of the future.

Mnemonic makes it clear that this process of conflict and migration is not only a recent experience. The play's cut-and-paste collage of different time frames from the last hundred years, telling the tales of modern pogroms and the survival stories of the characters' ancestors all around Europe, creates a strong connection between different historical times and locations. However, it expands its wings thousands of years further to also cover prehistoric European massacres. In one of the theories set forth by the archaeologists, it is suggested that the Iceman suffered the same fate as the inhabitants of Talheim in Germany. The mass graves discovered on the edge of the village suggested the murder of its entire population during the Neolithic period. The Iceman had to run away into the mountains to save his life. Here, the chilling similarity between ancient and modern massacres comes to the surface, displaying the fact that the characters' identities are parts of an even larger network of entangled histories. They are all the components of a larger whole, the temporal and spatial span of which reaches as far back as 5,000 years ago, a time period equal to recorded history, and encompasses a continent. What links them all together is, in fact, a collective past of massacre, violence, and running for their lives. At the end of her long journey in search of her identity, Alice finds herself in Bolzano, the exact same place where the Iceman is being displayed in a museum. Her journey does not lead to a definitive answer (this will be discussed shortly); she is instead confronted with the frozen body of the Iceman. As Casado-Gual argues, "a rushed nomad or, one could say, a mysterious migrant constitutes the enigmatic answer to her quest" (185). The play offers a further example

of a figurative application of the ideas of quantum mechanics. In the world of *Mnemonic*, characters become quantum systems whose shared experiences of displacement, exile, and immigration correlate them with each other and form them into an entangled network of connections that have overcome the boundaries of time and space.

This notion of connection unbound by time/space is artistically demonstrated during the final scene, in which the audience sees the naked body of the Iceman in his exhibition case in his museum in Bolzano – conveyed by a simple wooden table and metal frame (Appendix 1, Fig. 4) – surrounded by staring tourists. One by one, the tourists roll into the place of the Iceman on the display table in a choreographed sequence of images and pose as the corpse. As described by the stage directions, the actors "lay themselves down and roll off again, just as generation succeeds generation in a never-ending cycle" (75) (Appendix 1, Fig. 5). The substitution makes a 'family of man' statement, linking everyone, regardless of their temporal and spatial differences, in a powerful image of our common heredity and interconnection. We are all related, like the veins on a leaf, like the particles scattered in the universe.

Mnemonic is from and about Europe. It is a play designed for Europeans. It seems that by choosing their target audience from among Europeans, Complicite has guaranteed that after the powerful performance of *Mnemonic*, "its central image… its silhouette" as Peter Brook says (*Empty* 136), will be engraved forever on the memories of many of its spectators. Europe is home to people whose roots have developed outside the borders of the land on which they live now; people whose hearts are full of stories of many years of exile, struggle, and running for their lives; global citizens with patchwork identities who share the same collective memories of displacement, conflict, and sorrow as the play's characters. The unusual audience participation at the beginning of

Mnemonic takes its European spectators on a cosmic tour, from the minutiae of their own histories to that of a five-thousand-year-old body found in the Alps, and then to the interconnectedness of all generations. These stories perform the role of mnemonic devices, trigger their memories, and cause their brain to make broad connections between characters, themselves, and their ancestors. And when they reach a point where their memories end they begin to imagine. They begin to imagine the line of ancestors going down to 5,000 years ago standing behind them, and feel that they themselves are a part of this collective past; they themselves are a part of the process of "one generation succeeding another in a never-ending cycle" (Complicite, *Mnemonic* 75). *Mnemonic*'s powerful images of a common past and a common history turn the play into a mnemonic object that will remind its spectators that we are all related, however distantly.

In Complicite's work various objects become the sources of connection between distanced characters. McBurney's half-naked body is one of them. Through his body, a 5,000-year-old corpse and two contemporary characters, a waiting boyfriend and a theatre director, instantly connect with each other, despite their temporal and spatial distances. This connection is further emphasized when a pen draws the Iceman's tattoos on McBurney's body, now as Virgil, via live projection. This body also connects other distanced characters: at some point during Alice's phone call with Virgil, her face appears gradually on his chest, instantly linking them despite thousands of miles of distance between them (Appendix 1, Fig. 6). A simple chair becomes the meeting place of the Iceman and Virgil when it is interchangeably transformed into their figures. The Iceman's display table on which the characters lay themselves – similar to *Arcadia* and *Remembering Miss Meitner* – becomes a device that instantly fuses all boundaries of time and space. *Mnemonic* also repeatedly draws connections between Alice's father

and the Iceman: both were heavy smokers (61, 68); both had broken ribs so had to sleep on their left side (61, 65); and both left shoes for their succeeding generations, a pair of old outworn shoes (Alice's father) (51) and one grass-filled shoe (the Iceman) (26). These objects instantly connect the present to 5,000 years ago.

The instant link between characters from different timeframes and locations is also made possible through the dramaturgical technique of voice-over, employed in the form of a montage of the voices of different characters (64, 65). The simultaneous appearance of characters from different temporal and spatial dimensions onstage also creates this instant connection. For example, in Scene 15, the audience simultaneously sees archaeologists in the forensic lab, the police officers at the top of the mountain trying to pull out the Iceman's body, Virgil in his flat in London, and Alice somewhere out of time and space in her boyfriend's imagination. This simultaneous presence instantly links 'then' to 'now' and 'there' to 'here', in what can be seen as a metaphorical representation of the spooky connections of particles at a distance.

5.2.3 To Watch or to Be Watched? That's the Question!

Similar to Vivian's body in *W;t*, the body of the Iceman in *Mnemonic* becomes the battlefield of two contradictory views, one scientific and one humanistic, in a figurative enactment of the complementarity principle. The first view is presented by the scientists whose forensic experimentation on the Iceman turns the stage into a space for clinical observation. They are objective observers to whom the 5,000-year-old body is only another case for scientific investigation. Their view, as Campos explains, "anatomises the body, breaking it down into fragments of skin, teeth and bones, and detailing the Iceman's wounds" (327). In other words, their scientific view involves the

Iceman in a constant process of dehumanization and objectification conducted through an invasive act of forensic experimentation. This process is further emphasized when, due to the bizarre condition of its preservation, the body is placed in a museum alongside other historical objects. The Austrian and Italian governments' struggle over the ownership of the corpse and the journalists' questions about its monetary value also degenerate the Iceman into simply a valuable object for possession and media curiosity. The objectification of the Iceman is beautifully illustrated when a chair replaces Virgil's body on the table, as he is being examined by the archaeologists and journalists.

However, this objective view is constantly contrasted with Virgil's subjective humanistic view of the Iceman; while everybody is trying to have a piece of him, Virgil wants to know "How many mourned him when he disappeared? He has gone to the mountain, is that what they said? How many songs did he know?" (Complicite *Mnemonic* 32, 57). While the scientists are scrutinizing the Iceman's body and objects, he wants to know "How many children did he have? What word did he use to signify summer… or this place? How many songs did he know? Had he heard story of the flood?" (57)

This presentation of the Iceman as a human being with thoughts, feelings, and human experiences reaches its peak when the company of actors removes the chair that his body was transformed into from the table while the audience is being told the story of his final actions. Then a stream of living and breathing bodies replaces him on the table, indicating that he is brought back to life, now as a human being, since, as Freshwater explains, "he lives through their physical cohesion" (218). This constant conflict between two contradictory views towards the Iceman simultaneously presents him both as a subject and an object, suggesting the duality of his existence as a historical monument and a common ancestor.

This objective/subjective duality can also be discussed in relation to other characters in the play. *Mnemonic* is full of moments when the perceiving object and the subject of perception are fused. The first moment is when, at the top of the play, McBurney, who is being observed by the audience while giving his lecture, turns into Virgil, an observer in the audience watching him on stage. Virgil also plays the role of the observer when he watches the Iceman with others, and sometimes becomes the target of scientific investigation and media curiosity when he replaces the Iceman on the display table. The ability to be both observer and observed also expands to the audience; Casado-Gual argues that in the final scene of the play, when the tourists at the museum take the place of the Iceman on the table, the audience members, "become observers of their own memories and hence, in a way, are rendered participants in the play's entangled stories from the beginning" (187). The existence of the characters and the audience, at least within the boundaries of the play, is defined both as observer and observed. On Complicite's stage, therefore, human beings turn into uncanny creatures that, similar to the most basic elements in their bodies, namely particles, have acquired a dual identity, both a subject and an object, a human and a monument.

5.2.4 The Uncertainty of Memory-Generated Truth

Mnemonic's enactment of the workings of memory, that has at its heart the innate instability of the act of remembrance, provides a suitable context to discuss other implications of the new physics: the observer effect and uncertainty. Recognizing the significant role of subjectivity and imagination in the construction of the past, Complicite proposes that every act of recollection contains an element of uncertainty. This is why the characters' searches for certainty about their past is doomed to fail.

After a long journey across Europe, for instance, Alice eventually tracks her father down in a small village in Poland, but while recounting the end of her quest to Virgil on the phone, she declares that she cannot remember what happened, crying out "I can't remember" Virgil responds, "It's OK. It's alright. Then imagine" (Complicite, *Mnemonic* 66). This scene not only emphasizes the fundamental indeterminacy at the heart of memory, but also reinforces the ties between the act of recollection and imagination.

The archaeologists' search for facts about the origins of the Iceman also suffers the same fate. Similar to *Oxygen*, in *Mnemonic* the past remains a mystery due to the polyphony that subjective observation introduces into the play. Each one of the archaeologists interprets the life and death of the Iceman from their own subjective point of view: the Greek archaeologist believes that he was a Neolithic commercial traveler going from one side of the Alps to another (68); the English archaeologist thinks he was on a seasonal movement from lowlands to highlands (69); the French archaeologist supposes he was a doctor (69); and the US archaeologist proposes that he was a shaman (69). In this respect, the subjective element of observation traps the archaeologists in a process of unending speculation about the past, reflecting the impossibility of retrieving it in its totality. The open-endedness of Alice's story, along with the unresolved mystery of the Iceman's fate, proves the German maid's theory that "in the past, you always arrive too late" (46). The multiplicity of perspectives in the play and the indeterminacy that comes with it can be read as a metaphor for the important role of observation in the formation of quantum reality and the radical uncertainty that it posits in scientific knowledge of subatomic realm.

The play's representation of the fundamental instability at the heart of the recollection of the past is completed by Complicite's manipulation of props and

scenery. Throughout the play, scenery is constantly rearranged. The movement of stage props across the stage leads to the creation of new spaces and therefore changes the perspectives through which a situation is depicted. As Casado-Gual explains, "Since many of the scenes represent the characters' recollections, the change of spatial configuration bears a direct connection with the unstable nature of memory. These spatial modifications demonstrate… that memory is unreliable" (184). She goes on to describe how this movement of props and scenery depicts the objects as elements of a broken whole that can be reassembled from different angles. What conditions the distinction between situations, settings, and their respective recollection, in other words, is the composition of their fragments mirroring the act of remembering, which is dependent on "a capacity to recollect associated detail" (184). This movement of the scenery also emphasizes the spaces that are constantly formed between the pieces, suggesting the fractures that cause the discontinuity of memory.

However, the real strangeness of *Mnemonic* lies in the fact that it demonstrates humanity's continuing desire to dig into memory and construct the past, despite the fundamental uncertainty that characterizes the very act of recollection. The play's theatrical potential renders *Mnemonic* such a memorable piece that not only satisfies our desire to explore the past but also reveals to us that perhaps memory is not quite so uncertain; the images of the play and its silhouette have remained and will remain very bright and vivid in the memories of many of its spectators, no matter where, how, and when they watched it.

As one of the science plays in the category of 'science as director', *Mnemonic* uses dramaturgical and theatrical techniques to theatricalize the neuronal and psychic mechanism of memory. Complicite designs the performance in a way that together with the verbal discussion of science, the audience sees its demonstration on stage through

the company's manipulation of voice-overs, projections, scenery, and props. In its exploration of the working of memory, Complicite also discusses the concept of origin and the role memory plays in it. Mimicking the fragmented structure of memory, the narrative unfolds on stage in a discontinuous manner, taking quantum jumps from one time/space frame and one mini-narrative to another. Voice-overs, projected images, lighting, and the *mise en scène* facilitate this time/space travel enabling the play to overcome the Newtonian spatial and temporal limitations of the proscenium arch. Memory's process of connection-making is enacted on stage by means of props, words, and actors' bodies that function as mnemonic devices to connect different elements (characters and events) of the play in the audience's mind and on stage through centuries and continents, in what is also a representation of the complex entanglement relationship that quantum systems exhibit. The actors' physicality and props become the source of the theatrical representation of another new physics principle, namely the complementarity principle. Complicite uses a chair and the actors' bodies to depict the play's two complementary dichotomies: the scientific view vs. the humanistic view and subjectivity vs. objectivity. The multiplicity of theories surrounding the discovery of the Iceman and the uncertainty that is introduced at the heart of the play as a result is depicted through scenery and the arrangement of the props on stage. These aspects of *Mnemonic* are, this study suggests, figurative reflections of the observer effect and quantum uncertainty.

After discussing the ways in which mathematics is performed on the stage of *A Disappearing Number*, the following section will further discuss the performative paradigm within which post-quantum reality can be enacted.

5.3 Theatre, Mathematics, and the Aesthetics of Infinity: Complicite's *A*

Disappearing Number

The idea for *A Disappearing Number* was formed more than a decade before the production of the play in 2007, when Michael Ondaatje, then editor-in-chief of the Canadian literary magazine *Brick*, handed Simon McBurney G. H. Hardy's *A Mathematician's Apology* (1940) ("Barbican Centre"), an essay written by an early twentieth-century Cambridge mathematician who believed that mathematical imagination and mathematical creativity were the same as other artistic endeavours. Hardy writes that "A mathematician, like a painter or a poet, is a maker of patterns" (13). McBurney's copy of the essay opened with a biography of Hardy written by C. P. Snow, which included a vivid description of his collaboration with the Indian self-taught genius, Srinivasa Ramanujan: a collaboration that was described by Hardy as "the one romantic incident in my life" (qtd. in Albers et al. 81). Although this partnership involved no physical romance, there was a fairy tale ring to it that became inspirational source material for science plays such as *Partition* and *A Disappearing Number*, which follows the collaboration from their first encounter in Cambridge in 1913 until Ramanujan's return to India in 1919, and weaves it with an exploration of mathematical concepts that are demonstrated in their full complexity, beauty, and glory.

A Disappearing Number was first performed at Plymouth and then travelled across Europe and finally to the Lincoln Centre Festival in New York in 2010. The play juggles scenes from two stories and two interrelated time periods. The scenes from Ramanujan and Hardy's mathematical collaboration alternate and overlap with present-day scenes which record a romantic relationship between Ruth Minnen, a lecturer of mathematics at Brunel University with a research interest in Ramanujan's work, and her husband, Al Copper, an American born from Indian parents, a businessman with no

appreciation for mathematics or acquaintance with his familial roots. The two worlds are connected by Ruth's passion for mathematics and her fascination for Ramanujan's work. In order to study his mathematics in further detail, Ruth travels to India but dies of a brain aneurysm on a train speeding across the Indian countryside. Al subsequently visits India to follow Ruth's final steps; he meets Aninda Rao, a fictional physicist with a research interest in the connection between string theory and Ramanujan's mathematics. Two more present-day characters complete the narrative tableau of *A Disappearing Number*: Surita Bhogaita, a Brahmin student of African origin whose ancestors left India in 1869, and Barbara Jones, an Indian Bangalore-based BT customer service employee, who helps Al to get Ruth's cellphone number transferred to his name.

Mathematics is embedded into the content of *A Disappearing Number*: the audience is directly introduced to mathematical ideas through Ruth and Aninda's lectures, the former at Brunel University and the latter at CERN in Switzerland. However, the play's mathematical identity is fully formed when the complex mathematical concepts that it discusses are incorporated into its architecture. The iconic line in Hardy's *A Mathematician's Apology* that reads "mathematicians are makers of patterns" becomes the fundamental ingredient of the play. Complicite uses the underlying structure in mathematical patterns as a key schema to design different components of the play. *A Disappearing Number* opens in a university lecture hall where, after nervously thanking her audience for coming, an excited Ruth sets off on a lecture "to go through one or two very basic mathematical ideas that are integral to this evening so that the recurrent mathematical themes become clear" (Complicite, *Number* 21). She then explains that a mathematical 'sequence' consists of a set of numbers called 'terms' that follow a particular pattern. Some sequences have obvious patterns and some do not. "To find the hidden pattern," she continues, "you sometimes need to

look at them in a new way" (21). This opening scene gives the audience members a modest clue that in order to keep the track of the play they need to reformulate how they think of the experience of watching a play, and regard it instead as a process of math-pattern-making. Soon after this, they are confronted with a chaotic stew of images via voice-overs, sounds, video, and the actors themselves, that turns the universe of the play into a jumble of visual and aural experiences that constantly take them backward and forward in time from one location to another. Faced with this collage of fragmented pieces, the audience must begin to sort them out, put them in order, and make connections between them. They are, in other words, asked to constantly make patterns out of piles of chaotic fragments, necessary theatrical elements that are placed next to each other in the same format as the terms in a mathematical sequence regulated by complex hidden patterns.

In *A Disappearing Number* the process of pattern making and breaking is strictly ruled by a mathematical object called the partition function, an area in which Hardy and Ramanujan carried out significant investigations. Partition concerns the number of ways in which an integer can be broken down into a sum of smaller integers. For instance, 3 has three partitions (3, 2+1, 1+1+1) and there are five ways to partition 4 (4, 3+1, 2+2, 2+1+1, 1+1+1+1). This mathematical concept is the exact idea that is integrally imbedded in the play: a piece that is not continuous, that is constructed from fragments that are disjointed but whose sum forms the totality of the play. This element also functions as a complement to the play's main thematic principle: a time-less space-less interconnectedness of everything that continues on through infinity. However, since our actual world cannot physically contain the infinite, Complicite creates a universe where the mathematical concept of convergent infinite series, another field to which Ramanujan and Hardy made an extraordinary contribution, conceptualizes our relation

to the idea of infinite connectivity. In mathematics, when the sum of the terms of an infinite sequence equals a finite value, a divergent infinite series is created. For example, the infinite series of 1+1/2+1/4+1/8+1/16+1/32+… will eventually make 2. In *A Disappearing Number*, the characters constantly connect with each other to eventually form themselves into a sequence that encompasses the whole spectrum of time and space: a sequence whose individual terms melt into each other and become one entity only in infinity.

A complex patterned use of multimedia is key to *A Disappearing Number*. The performance's multimedia includes a whiteboard, blackboard, visualizer, overhead projector, and voiceovers. Voice-overs, both from absent and present characters, help the formation of the play's patterns, accelerate the backwards and forwards movement of time, and reinforce the connection between characters and events. The projected images also contribute to the overlap of past and present; images of contemporary India are projected on the screen while Ramanujan and other Indian historical characters enact past events nearby. The shadow-less light illuminating the front of the stage represents here and now, and the shifting light and shade at the back of the stage indicates the past and absent. The light changes also help actors suddenly disappear and reappear behind swiftly moving panels.

The frequent projection of mathematical formulae and the constant appearance of numbers dancing around the theatre space, like snowflakes, are central to the transportation of pure mathematics onto the stage (Appendix 1, Fig. 7). The projected numbers often exceed the frame of the proscenium arch and encompass all the action and all the space, as if reaching out to touch the audience. The dancing digits and mathematical symbols are also projected over the actors' bodies and onto surrounding screens to completely encompass them (Appendix 1, Fig. 8).

The idea of mathematical sequences is either conveyed by the actors frequently being positioned in lines of human 'series', or by video replays of the live action in the form of an endless sequence of images (Appendix 1, Figs. 9 & 10). The most explicit enactment of partition takes place in a remarkable scene late in the play. In this scene, characters from different time periods are onstage together: Hardy and Ramanujan are in Cambridge in 1915, Al is in the present locked in a lecture hall, Ruth is in Al's past phoning him, and Aninda is in the present giving a mathematics lecture in Switzerland. While Aninda is explaining different ways to partition the numbers 2, 3, 4, and 5, the actors act out different groupings with either their bodies or stage props. As Stephen Abbott explains, "For the partitions of 2, Hardy and Ramanujan move together and then apart. For the partitions of 3, the blocking takes Ruth and Al in and out of proximity with Aninda. For 4, Ruth unconsciously illustrates the various partitions using her 2 feet and 2 shoes" (233).

Ramanujan's mathematical ideas are also conveyed through the music of the performance. The complex rhythms of 'tabla', the Indian classical music that pervades the play, are by themselves mathematical because they involve precise calculations. These aural patterns are accompanied by Indian dance movements. At different points in the play, Ramanujan's wild creativity is demonstrated on stage through 'tihai', a highly syncopated Indian musical form involving tabla, voice, and dance.

The scientifically metaphorical style of *A Disappearing Number* and its reinforcement of themes of infinite connectivity and the aesthetic comprehension of mathematics in the sense that Hardy intended form the play's elements in a patterned mathematical fashion that requires a great deal of calculation to solve the equation of the play. Over the course of this journey into the world of mathematics the performative paradigm of *A Disappearing Number* also reveals characteristics that render it possible

to explore the play with reference to the implications of the new physics.

5.3.1 Infinite Time and Space

Complicite breaks through the temporal and spatial limitations of the Newtonian proscenium arch and allows the characters to inhabit Einstein's relative universe by employing the following theory: "There are no gaps between the numbers, like there are no gaps in time or space; they are continuous. And if time is continuous, then we are linked to the past and future. And if space is continuous we are linked to the absent" (Complicite, *Number* 30). Drawing an analogy with mathematical patterns, the time/space map of the play consists of a sequence of non-chronologically ordered spatial and temporal terms that are put together in such a way that they form a pattern of continuity through which their content, namely people and events, scattered across centuries and the world, connects with each other. This constructed space and time is formed by means of projected images, voice-overs, and objects such as chairs and beds that allow the instant transfer of the audience from one temporal/spatial dimension to another.

The opening scene is set in the past, five years before the present, which is the night Al spent locked in a Brunel University lecture hall. The audience is watching Ruth on the stage giving a mathematics lecture that is suddenly transferred to the future where Aninda and Al are getting in a taxi in India to go to Ramanujan's house in Chennai. The audience sees an image of Chennai projected on the screen behind two plastic chairs, suggesting the taxi in which the actors sit and ride towards their destination. Once there, Aninda explains that Ramanujan wrote his first letter to Hardy in 1913 in his house, which was located opposite the Goporam temple. Then through

Ramanujan's voice-over reading the letter and projected images of the temple the audience is instantly transferred to 1913 and Ramanujan's house. It is then back in the lecture hall in Scene 2 to see Al approaching Ruth in pursuit of her phone number. In Scene 3, the audience travels to different points in time and space within a matter of seconds: through the technique of voice-over, it goes to India in 1869 to hear a young Indian woman's memory of her family leaving the country never to return; to New Delhi in 1946 where Churchill declares India's independence; to London in 1945 where a BBC reporter announces the death of Hitler; to Downing Street in 1939 where Chamberlain broadcasts the news that Britain is at war with Germany; and to a Harvard Conference on Arts and Science in 1936 where Hardy gives a lecture about Ramanujan after the latter's death. The audience then sees the figure of Ramanujan in Chennai in 1920, lying on the stage while his mother, a few hours before his death, is feeding him sips of diluted milk. Immediately after, in the distanced upstage, the audience sees Hardy on his deathbed in 1947, with a view of Cambridge behind. The lights fade as a sudden noise of a train approaches and a view from a train as it speeds through the Indian countryside appears on the screen. The audience is then transferred to the near past to witness Ruth's collapse and eventual death on a train from Chennai to Kumbakonam.

These fast and fluid shifts between different historical time/space frames with no seeming connection between them pervade *A Disappearing Number*. Complicite's presentation of all time and all space as always there with no gap or break between them serves another purpose, namely to illustrate that the mathematical patterns of infinity can become a source with which we can relate to infinite time and the infinite absent. The spatial and temporal terms of the space/time sequence of the play, in other words, continue forever, so that we are united with infinity. This sense of mathematically

structured 'infinity travel' through time and space is beautifully illustrated in Scene 3 through Al's act of counting: 1, 2, 3… He stops but his voice continues to count up. He listens and then begins to count backwards: -1, -2, -3. Again he stops speaking but his voice continues. Now we hear the counting voices in both directions. This counting forwards and backwards from 1 and their continuing to count after their creation has ceased reinforces the idea of the continuity of time and space until infinity; we leave the immediately present, count backwards into the past, join infinity, count forwards into the future, join infinity, and continue like that forever. This impression of the specters of continuing time/space is illustrated when in the same scene the audience sees the action of the forestage projected on the screen but with a four second delay. This pattern of continuation keeps repeating throughout the play. In addition, a company of nine actors who are nearly always on stage, continuously switching contexts, contributes to this sense of infinity; in the same scene, after every time/space shift, the actor whose presence on stage has caused the forward movement into the past walks back through the screen, where he/she entered from, followed by the company disappearing one at the time into the darkness of the screen. The screen becomes a door into another world through which people step into infinity.

The fast and fluid time/space travel in *A Disappearing Number* creates a chaotic jumble of events that are grabbed from different temporal and spatial dimensions to be placed next to each other. The play's Einsteinian employment of time/space leads to an episodic, fractured narrative that unfolds a series of parallel stories simultaneously. But is there any pattern to these time/space and narrative fluctuations? The answer will be provided after a discussion of the play's narrative structure, which will also explain the connection between *A Disappearing Number* and the concept of the quantum leap.

5.3.2 Mathematicians Calculate the Narrative

Similar to *Mnemonic*, *A Disappearing Number* consists of a main narrative within which there is a set of interconnected mini-narratives (six) whose fragments constantly interrupt each other's linear continuous flow and force one another to make constant frog-leaps from one temporal point to another within their own time/space frame. Due to their interconnectedness, the mini-narratives also contribute to each other's development by containing some of each other's fragments. This makes the play's main narrative a jumble of separate images, moments, episodes, and glimpses, whose significance and relations to each other and to the mini-narratives are not immediately clear. The audience members are therefore required to constantly analyze the fragment release process to make and remake the necessary connections.

The discontinuous narrative structure of *A Disappearing Number* makes the fragment hunting a complex process with different stages. The audience first needs to determine to which mini-narrative the released fragment belongs, then to locate it on the temporal/spatial spectrum of the identified mini-narrative, and finally to provide a linear sequence of chronologically ordered fragments that are tied together with the string of logic. It eventually needs to analyze the linear mini-narratives in relation to each other to come up with a linear, continuous main narrative. This complex process of fragment hunting and narrative assembly gives the audience the unique chance of getting personally involved in the scientific content of the play and creating by themselves beautiful and provocative patterns from complexity. In doing so, Complicite not only shares the experience of pattern making with the audience, but also places mathematical thinking at the heart of the play; the audience sorts through the fragments, arranges them, connects them to create patterns. And this is the same process that

mathematicians go through when, to quote Stephen Abbott, "training their focus on some unfamiliar corner of the mathematical landscape" (234).

In order to clarify this point, it is necessary to discuss the aforementioned process with reference to at least one of the mini-narratives of the play. The first fragment of Ruth's narrative, for instance, is released in the very first scene, where she is giving a lecture about Ramanujan's mathematics in her far past. The linear flow of her narrative is suddenly interrupted by fragments from Aninda's, Al's, and Ramanujan's narratives, forcing it to jump to Scene 2, where she meets Al for the first time after the same lecture in the first fragment. Ruth's narrative then disappears, making way for a jumble of fragments from other mini-narratives, only to reappear again at the end of the scene to show a few seconds before her collapse on the Chennai train. In Scene 4, a fragment from Al's mini-narrative, picturing him in the lecture hall collecting his wife's things, releases the fourth fragment of Ruth's narrative, namely her death. The next jump is made to Scene 5 where the audience sees Ruth in her near past reading Ramanujan's notebooks in a library in Madras. Jumping over the fragments of Al, Hardy, Ramanujan, and Aninda's narratives, Ruth's narrative lands in Scene 7, releasing the sixth fragment, that shows Ruth and Al's decision to have a baby in her far past. Scene 8 shows Ruth having a conversation with Surita about Ramanujan on the Chennai train a few minutes before her death. Her narrative then appears again in Scene 10 showing the pregnant Ruth in her far past. The ninth fragment is released in Scene 11, at the heart of a clutter of other mini-narratives' fragments, revealing to the audience that Ruth had a miscarriage and lost the baby. The next jump is to Scene 12 where the near past fragment containing Ruth's decision to go to India is released, along with several other fragments related to other mini-narratives. In Scenes 13 and 14 Ruth's narrative flows freely without any interruptions but in a non-chronological order: the

audience first sees Ruth in her far past explaining to Al why she is going to India, and then is taken to Ruth's future, seeing Surita informing Al of his wife's death over a phone call. The final jump of Ruth's narrative is to somewhere out of time when, after her death, she appears onstage to express her love for her husband. Closely following the narrative jumps between different temporal dimensions and analyzing the complex fragment release process, the audience must collect all thirteen fragments of Ruth's narrative, arrange them chronologically, and eventually create a linear continuous narrative pattern. The same process applies to other narratives of the play. The play's narrative fragments seem to be following the same pattern of behavior as particles do while orbiting around the nucleus of the atom; it is another example of how the implications of quantum mechanics provides inspiration for the structure of science plays. But what determines the arrangement of the terms of the main narrative sequence of *A Disappearing Number*? Is there any formula for placing the fragments next to each other and drawing connections between them? The answer lies in the play's central thematic principle: boundless connectivity.

5.3.3 Boundless Connectivity

The complex network of interconnected relations that Complicite creates between distanced events – through the technique of message exchange – and distanced characters – through establishing similarities – enables us to explore the theory of entanglement with regards to the play. In *A Disappearing Number* the stimulus that triggers the instant and haphazard narrative jumps is thematic similarity. Within the larger scope of the main narrative, the force that determines the arrangement of the fragments of the mini-narratives is the content of the fragments. In other words, the

fragments of the mini-narratives that are thematically connected are placed next to each other to form the main narrative sequence. The thematic pattern that guides the narrative development renders the plotline chaotic and haphazard but serves one main purpose, which is the reinforcement of the play's central thematic principle: everything is interconnected through time and space.

This thematic similarity also gives the dynamics of the chaotic time-space map of the play an appearance of order and pattern. *A Disappearing Number* uses a complex system of message exchange to reveal patterns and instant connections between temporally and spatially distanced terms of the play's time-space sequence. The event being enacted onstage instantly interacts with another event in another unit of time and space by sending it a message, and becomes thematically entangled with it. As a result of this, the terms in the time-space sequence are mysteriously embedded and entangled with their preceding and following terms, breeding a beautiful pattern of thematically connected elements; they find each other, interact with each other, and become entangled, despite whatever vast distance lies between them. In Scene 3, for instance, what gets the young Indian woman in 1869 entangled with Churchill in 1946 is India's nationalist movement. In 1860, under the sovereignty of the British Empire, thousands of indentured Indian laborers were sent to Natal in South Africa to develop the sugar industry. However, as a result of efforts made by Indian nationalists, not only was the indentured labor to Natal terminated, but also the Indian Independence Act was passed by the British Parliament in 1946. This event is instantly followed by a thematically similar event, the death of Hitler in 1945; immediately after the end of World War II, India gained her independence because many years of war against Germany had destroyed the economy of Britain to such an extent that it could no longer financially support its armed forces and was therefore not able to contain the growing freedom

movements in its colonies, including India. It therefore seems fair to say that Hitler played a lead role in India's independence. Accompanied with the sounds of war, this event is instantly linked with the one in which Britain's involvement in the war against Hitler is announced, followed by Hardy's lecture about Ramanujan's death, whose health worsened in England because of the scarcity of vegetarian food during the war. From here on, the common theme connecting the rest of the scene's events is death; three deaths are entangled across time and space, Ramanujan's, Hardy's, and Ruth's.

Another example from Scene 8 will help clarify the point. The audience sees Ruth and Surita on the Chennai train having a conversation about the significance of the string Brahmin men wear across their body. Right after this, Aninda appears onstage explaining the restrictions Ramanujan had to obey as a Brahmin about "crossing the water from native lands" (Complicite *Number* 53). The audience then hears Hardy's voice-over in Cambridge advising Ramanujan about whom to contact in India with regard to travelling to England. Immediately following this, the audience sees Ramanujan in India and hears his voice-over informing Hardy of the date his ship will leave Madras towards London. Then the voice-over of the young Indian woman in 1869 is heard describing the day her parents left India on a boat. *A Disappearing Number* is full of these hidden connections and complex entanglements. The thematic arrangement of these distanced events determines the development of the time-space sequence of the play. In other words, the pattern that governs the order of succession in the play's time-space sequence is a thematic relationship that is entirely dependent on a complex process of message exchange between the events that the members of that sequence contain. In doing so, *Mnemonic* creates a microcosm in which the governing rules are those of the subatomic realm: distanced quantum elements getting entangled through the instant transfer of information.

Together with the process of message exchange, the strong similarities that Complicite establishes between the characters gets them instantly entangled beyond the boundaries of time and space and reinforces the sense that the play can be read in the light of ideas of quantum entanglement. This character similarity is suggested by two elements: mathematics and Indian blood. Ramanujan and Hardy in the early twentieth-century are connected with Ruth in the twenty-first-century through their passion for numbers and mathematics. American Al and British Surita in the present day are linked to the historical Indian Ramanujan through their Indian blood. Aninda and Barbara in the present day are connected to other past and present characters scattered across the world through both numbers and Indian blood. These characters from different temporal and spatial dimensions become entangled once their similarities are established and remain the same until the very end of the play. This creates a pattern of relations amidst the chaos of the play that, although it is hard to grasp at first glance, gradually reveals itself in the form of a web of hidden connections.

This pattern of connection between distanced characters is also reflected in their explorations of the mathematical landscape in pursuit of truth and understanding. Each character starts a solitary journey across the world of mathematics, the destination of which is unification with other characters. This unification is illustrated through the mathematical theory of partition, echoed in the play through many images of division. The stage is divided into different parts by several screens, constantly shifting up and down and revolving around the characters. The scenography of the play also contributes to this sense of division; because of the screens and light effects, the characters seem to be isolated in different areas of the stage and cut off from one another (Campos 331). This division is also echoed in the play by the separations that the characters have to endure: Al is parted from Ruth, for example, due to his inability to understand her

passion for mathematics, and is alienated from his past and cultural roots as an Indian. Hardy is also distanced from Ramanujan due to the differences in their methodologies, as the latter was famous for achieving his theorems through imaginative mathematical leaps, and this was strange to the former who, as Louise Whiteley puts it, "[was] raised as he was on a strict diet of logical proofs" (48). However, as a result of the characters' quest for truth and understanding, a beautiful pattern emerges that makes these divisions the source of entanglement and connection. While locked in the lecture hall and thinking through his past with Ruth, Al reads Hardy's *A Mathematician's Apology*, a book that helps him get an insight not only into the life of Ramanujan and his romantic and passionate relationship with mathematics, but also into the mind of his wife as a mathematician. Hardy's book and Al's memories of Ruth take him on a journey, the destination of which is a union with his wife and his familial roots. While Ruth journeys across India in search of mathematical truth and a sense of ultimate connection and belonging, she prepares the way for Al looking for his roots and understanding in the same place. India for him becomes a multifaceted, abstracted space containing a completeness of everything: a better understanding of his wife and her passion for mathematics, as well as his origins as an Indian. Once Ruth is dead, Al has to find a new home, a new place to belong to, a place that turns out to be his country of origin.

Ramanujan and Hardy also make the same truth-seeking journey across the land of mathematics. Ramanujan travels from Madras to Cambridge in pursuit of mathematical truth, and Hardy's collaboration with him puts him on a journey that takes him beyond the dry and rigorous practical applications of mathematics to the realm of its intrinsic aesthetic value. This impact is most evident in *A Mathematician's Apology*, a book he wrote at the end of his life: "[Real mathematics] must be justified as art if it can be justified at all" (43), is how the nature of mathematics is summarized in the

book. Similar to the characters in *Mnemonic*, the characters' search for self and truth in *A Disappearing Number* also involves travel, both physically and mentally, across countries/continents and within the realms of memory/mathematics.

The connection that Complicite established between these distanced and near characters (Ruth and Al, Ruth and Ramanujan, Ramanujan and Hardy), after going through a long process of division, underlines the metaphorical role of the partition function: the characters become the elements of a whole which first divides to eventually unite to equal the whole. This unification of characters is beautifully illustrated in the very last scene, when the distanced characters unite with each other at the sacred Cauvery River in India. Having understood Ruth's passion for mathematics, Al decides to throw a piece of her chalk, the same chalk with which she wrote numbers and equations, into the Cauvery River where Ramanujan used to swim. Meanwhile, we hear Hardy's voice-over, "I still say to myself, when I am depressed or forced to listen to pompous and tiresome people: 'Well, I have done one thing you could never have done, and that is to have collaborated with Ramanujan on something like equal terms'" (Complicite 88). The river becomes a place where distanced characters can reunite with each other and become instantly entangled. These numerous interconnections indicate the power of mathematics as a time-less space-less phenomenon to interconnect time-bound and space-bound humans, no matter how far apart they are. A unification of divisions generated by mathematics.

In order to illustrate the instant connection between distanced characters, Complicite uses plenty of theatrical techniques, such as voice-overs, characters dissolving into the darkness of the screen and their sudden reappearance again through the screen, noises of objects such as trains, airplanes, and cars. These techniques enable Complicite to make characters instantly travel across the spectrum of time and space to

the aliveness of the stage to connect with one another. But this connection is best illustrated through the overlapping of images. While being trapped in the lecture hall, Al places Ruth's belongings on an OHP: a piece of chalk, a scarf, Ruth's passport, Hardy's *Apology*, Ramanujan's picture, a *Rough Guide* to India, and a picture of Ruth and Al in bed. Objects from different time/space dimensions are gradually accumulated on the OHP, making it a site where past and present and here and there can instantly connect. Similar to *Arcadia*, *Remembering Miss Meitner*, and *Mnemonic*, *A Disappearing Number* uses the trick of having a simple space, in this case an OHP, as the centerpiece on which large temporal and spatial distances become a matter of a few centimeters and seconds. Complicite, in other words, create a theatrical microcosm where the same rules of entanglement that govern the tiniest elements of the macrocosm take control of the stage and define the connections played out thereon.

But the link between characters does not conform to the rules governing our actual world; in the universe of the play these connections continue forever until infinity. Here, the mathematical content of the play once again conceptualizes our understanding of connection and entanglement. The characters' abstract considerations of infinity are frequently overshadowed by the reality of death and loss, which provides a cruel contrast to Ramanujan and Ruth's research on infinity. However, the mathematics is also introduced as an effective device to create patterns with which the dead and absent can relate to the alive and present. In the world of mathematics, they become two lines stretching away forever, getting closer and closer to each other though never quite touching, except in infinity: "those two lines do actually meet… in infinity. The impossible *is* possible" (Complicite, *Number* 35), Ruth explains. By letting go of the governing laws of the actual world and allowing the patterns of mathematics to take control, the metaphorical structures for human relationships find the necessary space to

emerge. Convergent infinite series such as 1+1/2+1/4+1/8+1/16+1/32+… = 2 become a metaphor for the impossible union of human beings. Here, science becomes the mathematics of love and relationships, an infinite romantic entanglement between men and women. The love that exists between Ruth and Al continues forever until they meet each other again in infinity and reunite to become 2. This union of characters is again illustrated by the powerful final stage image at the Cauvery River. As Al stands there, Ruth appears behind him and touches his shoulder. She then explains the union of lovers in 'elsewhere', namely infinity, as follows:

> Al, you know that box of mine with all that stuff and inside you found a piece of chalk. Do you know now why it was there? … What reconciles me to my own death more than anything else is the image of a place: a place where your bones and mine are buried, thrown, uncovered together. They are strewn there pell-mell. One of your ribs leans against my skull. A metacarpal of my left hand lies inside your pelvis. (Against my broken ribs your breast like a flower.) The hundred bones of our feet are scattered like gravel. It is strange that this image of our proximity, concerning as it does mere phosphate of calcium, should bestow a sense of peace. Yet it does. With you I can imagine a place where to be phosphate of calcium is enough. (91)

Ruth's voice counting numbers until gradually fading out accompanies this final image. When it fades and the play is over, the voice keeps counting fainter but still repeating. For a while at least, through the magic of theatre, the numbers seem to be counting infinitely. As Hardy explains in *A Mathematician's Apology*, "Archimedes will be remembered when Aeschylus is forgotten, because languages die and mathematical ideas do not. 'Immortality' may be a silly word, but probably a mathematician has the best chance of whatever it may mean" (12). And indeed the offspring of Hardy and Ramanujan's collaboration is a mathematics that has guaranteed its immortality through the pages of history. Two opposite forces, Ramanujan and Hardy, collide, unite, and make a complete mathematical whole in a microcosmic enactment of one of the most complex equations of the universe: the wave-particle duality that characterizes quantic entities.

5.3.4 Mathematical Opposites Collide

A Disappearing Number juxtaposes two extremely different approaches to mathematical creativity. The first approach relies on an unusual mathematical intuition embodied by Ramanujan, a religious genius with no formal training in mathematics whose theorems, to use Du Sautoy's words in his introduction to *A Disappearing Number*, "were spilling from his mind thanks… to the inspiration of his goddess Namagiri" (Complicite, *Number* 14). The second approach is based on the rigors of a western definition of logic and proof practiced by Hardy. The contrast between the two mathematicians is emphasized in the play through the juxtaposition of Hardy's carefully planned life as a Cambridge university don with Ramanujan's as a man of intuition and inspiration. Hardy is depicted on stage drinking his coffee while reading a newspaper, riding his bicycle to college, enjoying a game of tennis, and writing his equations on sheets of paper in his college surroundings, while Ramanujan's wild creativity is conveyed through Indian dance and tabla music. At some point in the play, two actors, one writing down the equations, the other enacting the thought process through dance movements, both play Ramanujan's character (Campos 330).

In the course of their mathematical research, Ramanujan and Hardy encountered intercultural and interpersonal challenges that arose from their different working methods and cultural backgrounds; Hardy's western approach which favored logic and proof constantly clashed with Ramanujan's instinctive and inspirational approach to mathematics, stemming from his Brahmin upbringing. His creative dynamics was highly rooted in intuition, allowing him to make his wild theorems from unexpected

relationships in unlikely places.[41] As Hardy noted, "It seemed ridiculous to worry him about how he had found this or that known theorem, when he was showing me half a dozen new ones almost every day" (qtd. in Albers et al. 60). It was therefore up to Ramanujan to supply the raw material and up to Hardy to provide the rigorous proofs that would make their papers eligible to be published in western journals. "It was a real cultural clash", Du Sautoy explains, "like trying to marry the traditions of western classical music with the ragas and tablas of India" (Complicite, *Number* 14). But this union of opposites, an inspirational and intuitive mathematics with a rigorous proof-based one, gave rise to very powerful analytical methods in mathematics. This unification of opposites is depicted on the stage by fusing Indian and Western sounds and rhythms and the superimposition of images. At one point in the play, the image of Ramanujan is projected over Hardy while he is working on mathematical equations at his desk (Appendix 1, Fig. 11). In another memorable scene late in the play, as a half-naked Ramanujan is sitting on the floor rapidly writing equations on a small blackboard, the audience is presented with a tihai while papers are flying about and Hardy is circling around Ramanujan on a bicycle with numbers being projected everywhere.

By choosing the confrontation between two mathematicians with two opposite mind-sets as the focus of the play and by creating such a strong connection between them, Complicite suggests that at the heart of mathematical research, there are two contradictory and yet complimentary forces (intuition and logical proof) that work most effectively together to eventually create a work of genius.

In *A Disappearing Number* Complicite uses dramaturgical techniques and theatrical strategies to perform complex mathematical theories of partition and infinity.

[41] There is a famous anecdote about Hardy and Ramanujan's collaboration: Hardy explains, "I remember once going to see him when he was ill at Putney. I had ridden in taxi cab number 1729 and remarked that the number seemed to me rather a dull one, and that I hoped it was not an unfavorable omen. 'No', he replied, 'it is a very interesting number; it is the smallest number expressible as the sum of two cubes in two different ways'" (qtd. in Albers et al. 60).

Different units of time and space are put together in the form of an Einsteinian continuum, as if they are the terms of a mathematical sequence that continues forever. The company's skillful use of voice-overs, projected images, and screens helps with the conveyance of the continuity of time. This temporal travel gives the narrative structure a jerky look, constantly shifting from one time frame/narrative to another. The play begins with the theatrical illustration of the mathematical concept of partition through theatricalizing the characters' separation from each other by means of scenery and props, and ends in connection. Spatially and temporally distanced characters unify across time and space, in a dramatic enactment of the 'spooky' behavior of particles in the quantum realm. Projected images, props, voice-overs, and the *mise en scène* beautifully convey this sense of connection in the play. The complex message exchange that governs the arrangements of the scenes also emphasizes the play's metaphorical engagement with the entanglement principle. The unification of the logical Hardy with the intuitive Ramanujan to create mathematics in the play is complementarity theory at work on the human level. This unification of opposites is presented through characters' bodies, music, images, and voice-overs. The plays' reliance on performance to communicate science on stage and the centrality of science in the plays place *Mnemonic* and *A Disappearing Number* in the third category of science plays, 'science as director'.

Conclusion

The relationship between science and theatre has primarily been defined as one of conflict and opposition, and these two fields have been considered to lie at the two opposite ends of the spectrum of human activity. Between science and literature there is, Norris argues, "those rigid (and purely conventional) lines of demarcation that have hitherto been drawn between the natural and the human sciences, or again, between 'science' as a mode of knowledge accountable to rigorous (cognitive) standards of enquiry and art as a realm of creative or imaginative freedom" (103). If theatre is regarded as representative of literature and the humanities in general, this debate can be summarized with reference to Snow's famous lecture on the "Two Cultures". Many critics and scholars, then and now, believe that "the notion of incompatibility between science and theatre remains deeply ingrained" (Orthofer) and that every time they are put together, the result is bad plays (Soloski). The present study, however, proves the contrary. It shows that science plays, with their employment of real scientific ideas and discoveries, and featuring scientists for pedagogical, metaphorical, or social and ethical purposes have created a genre that, as Shepherd-Barr argues, defies "C.P. Snow's pessimistic forecast of a widening rift between the two cultures and instead encourages each culture to learn about the other" (218). This study takes this defiance one step further by suggesting a new framework, a scientific one, to be used for the analysis of a range of plays and performances, and also by positing that there exist works of art and literature that specifically embody the implications of new physics.

This study has endeavored to categorize science plays based on differences in the functionality of science within the plays and their different modes of addressing it onstage. The first two categories are similar in their mode of representation (text) but

differ in the specific function that science enacts within them. In the first category ('science as supporting character') science is tangential, since the central focus is on an issue raised by science or its practitioners. Science plays in this category use scientific ideas as appropriate contexts within which to explore the ethical and social implications of science. In these plays, therefore, science is imposed superficially, and is not used metaphorically or explained accurately. In the second category ('science as leading character'), on the other hand, science is central due to it being used for metaphorical or pedagogical purposes. These plays offer either an accurate and detailed description of scientific concepts or embed them into the structure of the play so that different aspects of it can be defined with relation to the science in question.

The third category ('science as director') is different from the other two in its mode of presentation since the actual science is embodied in the expressive form of the performance rather than in the text. In this category, the dramaturgical techniques and theatrical strategies are designed so that they provide a visual exploration of scientific processes and concepts on the stage. Science provides these pieces, therefore, with structuring schemata and visual principles. This category and the second category are similar in that they both give priority to science.

Regardless of their differences, however, all science plays attempt to explore human problems with direct or indirect reference to real science. They predominantly share some or all of the following critical features: a complex ethical/social discussion, real or imaginary scientists as protagonists and historical events as the dramatic focus, a clear depiction of the tribal culture of the scientists, plausible descriptions of scientific facts, a metaphorical usage of science, and the conveyance of science through dramaturgical strategies and theatrical techniques.

This study has also argued that new physics can be used to create a theoretical framework to discuss science plays, regardless of the scientific idea that they engage with, because the impact of new physics on playwrights and theatre practitioners has been greater than simply a concrete and explicit presentation; the impact has in fact formed the way they perceive the world around them and the way they perceive reality, and its implications are clearly reflected in their works. Relativity theory brought time and space, previously perceived as absolute and separate, into relativistic relations. The implications of this for contemporary science plays were a rejection of the conception of time and space as possessing single unified patterns, and instead treating different temporal and spatial units (past, present, future, and here and there) as a continuous whole. Quantum mechanics showed that in their movement around the nucleus inside the atom, electrons jump from one orbit to another without passing through the intervening space, providing a model for discontinuity. For contemporary science plays, this is reflected in an episodic and fragmented narrative structure that constantly jumps from one time frame to another, demanding a great deal of attention and involvement on the part of the audience.

Quantum mechanics also suggests that the tiniest elements of the universe (particles) contain a paradoxical complementarity of particle-like and wave-like behaviors within themselves. Contemporary science play practitioners also impose a both-and structure on their plays, putting binary dualities together in the form of single entities. In the invisible and inaccessible realm of quantum mechanics there exists a spooky connection between particles, despite whatever vast distances come between them. They connect with each other, interact with each other, and form entangled pairs. The seemingly impossible connections that contemporary science plays establish between distanced characters and events mirror this quantum principle.

Quantum mechanics recognizes that subatomic reality changes with observation and thus places great importance on the role of the observer. Contemporary science plays reflect this by allowing seemingly divergent voices and opinions, with equal credit, to coexist with one another. The observer effect imposes a radical indeterminacy on the perception of subatomic reality, just as polyphony and a multiplicity of perspectives make a single determinate meaning impossible to construct in contemporary science plays. No matter if Heisenberg, Bohr, Oppenheimer, or Einstein are not the protagonists, or their theories do not turn into metaphors or are not explicitly outlined, they still rule the territory of the science play and the minds of those developing it.

In this study the analysis of the genre of the science play within the paradigm of new physics has focused on plays and performances written and performed after 1990. However, since the genre began in the seventeenth century, long before the emergence of the theory of relativity or quantum mechanics, it would surely be worthwhile to examine the intersection between the dominant scientific paradigms in different eras and the science plays of the time within a historical context, to eventually get a sense of how science has affected the genre throughout the centuries.

The new physics theory of the science play can be applied to many other plays and performances written after the discovery of the theory of relativity and quantum mechanics, most obviously plays and performances that do not explicitly engage with science. The twentieth-century scientific view of reality has left its mark on the entire mental world of writers and artists, regardless of the content of their work. It is therefore possible to expand the scope of the new physics framework further to also include plays and performances that are not about science and scientists. Examples of subjects for further study might be Tom Stoppard's *Rosencrantz and Guildenstern Are Dead*, Neil

LaBute's *This Is How It Goes*, Marsha Norman's *Night, Mother*, and Steve Dietz's *Inventing Van Gogh*. An alternative would be to expand the temporal and cultural scope of this study to other cultures and other timeframes – for example from the mid-twentieth century to the present – to provide a more exhaustive and comprehensive analysis of the intersection between new physics and theatre.

A further possibility would be a comprehensive examination and contextual overview of performance-based science plays. The new wave of science-informed performances and theatrical events, particularly in the last two decades, and the considerable critical acclaim and popular success that they have been achieving, have created a phenomenon that deserves detailed scholarly attention. This could be an examination of how theatre practitioners have depicted the culture of science and scientific ideas though the technologies of visual imagery, the actor's body, and virtual technology, for example.

Both theatre and new physics are attempts, despite their essential differences, to investigate and explain the world and to locate our position within it. The perception that new physics provides of external reality can radically change our artistic, literal, and theatrical sensibilities, and these communications can and should be traced. The primary research question in this study has clearly been answered: new physics can be used to create a new paradigm within which to discuss contemporary science plays. The astonishment generated by the way new physics transformed the classical perception of reality as absolute, continuous, local, definite, and objective was so great that all thinkers in every field felt its implications. A skeptic might argue here that regardless of the greatness of the redefinition of reality as relative, nonlinear, paradoxical, subjective, indefinite, and nonlocal in new physics, its impact cannot immediately and directly affect science play practitioners because writers and theatre practitioners do not read

physics journals and could not understand the mathematical and theoretical complexities if they did. These sceptics would be wrong because, as Strehle argues, "changes in physical theories inspire changes in a culture's general attitudes, and literature both responds to and shapes these assumptions. Physics and literature inhabit the same planet, however divergent their discourses about it may be" (8). And as shown in this study, new physics has indeed played a very significant role in changing concepts of the world for contemporary science plays.

A further area to which this research on the intersection between the post-quantum reality and contemporary science plays might contribute is our understanding of postmodernism in art and literature. The metanarrative of postmodernism provides a disturbing and tremendously fluid perception of ourselves and the world; a perception that contains no foundation nor firm grounding. Flux is replaced by foundation in such a way that "the world and/or our vision of it in postmodernism comes to us in episodes, particles, glimpses, and snapshots, in random moments, and creates possible epiphanies, disruptions, and disconnections, a plurality of voices and perspectives, leaving us with the notion that reality forever remains mysterious, and unknowable" (Coale 36). Postmodernism reveals a vision of reality which is extremely similar to the perception presented by new physics. The investigation of the intersection between contemporary science plays and the post-quantum reality makes a significant contribution to our understanding of postmodern literature and art.

The plays discussed in this study are among the best at depicting the intersections between new physics and the science play, as well as in their engagement with scientific ideas. In a world dominated by science and scientific thinking, it is impossible for playwrights and theatre practitioners, especially those interested or involved in science, not to be affected by the changes that the dominant physical reality

imposes on general cultural attitudes. This is a domain that will continue to grow until another revolutionary scientific theory comes along to change our perception of reality even more radically than before.

Appendix 1

Figures

Fig. 1. Joseph Wright's "An Experiment on a Bird in an Air Pump" (1768).

Fig. 2. The actors' silhouettes seen through a plastic curtain. Source: http://www.complicite.org/productions/Mnemonic.

Fig. 3. The actors' silhouettes seen through a plastic curtain. Source: http://www.complicite.org/productions/Mnemonic

Fig. 4. Virgil as the Iceman on the display table in the museum. Source: Tristram Kenton. https://uk.pinterest.com/pin/492159065503408498/

Fig. 5. Actors taking turns assuming the place of the Iceman on the display table. Source: Michael Levine. http://www.michaellevinestudio.com/ajax-reader/nojs/123/

Fig. 6. Alice's face projected onto Virgil's body. Source: http://www.thedesignschool.co.uk/thefilter/2016/01/11/mnemonic-by-complicite-theatre-company/.

Fig. 7. Numbers falling down like snowflakes. Source: Stephanie Berger. http://londonist.com/2010/09/theatre_review_a_disappearing_numbe.

Fig. 8. The projection of numbers and mathematical equations onto the actors. Source: Joris-Jan Bos. http://ccunningham.co.uk/shows/a-disappearing-number/.

Fig. 9. Actors positioned as a human series. Source: Sara Krulwich. http://www.london-attractions.info/london-blog/2010/a-disappearing-number-at-the-novello-theatre.htm.

Fig. 10. Multiple video frames of the live action. Source: Sara Kurlwich. http://www.nytimes.com/2010/07/17/theatre/reviews/17disappear.html?_r=0.

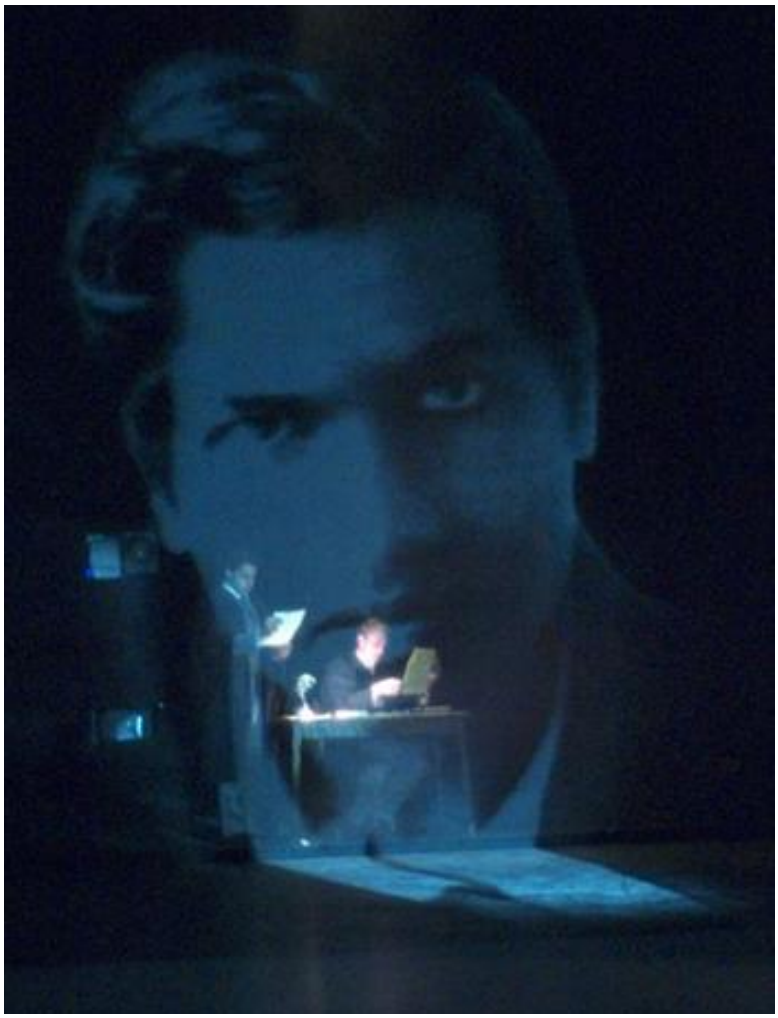

Fig. 11. An image of Ramanujan projected over Hardy. Source: Robbie Jack. https://plus.maths.org/content/disappearing-number

Appendix 2

Existing Science Plays

Tony Harrison's *Square Rounds* (1992)
Tony Kushner's *Angels in America: A Gay Fantasia on National Themes* (1993)
Tom Stoppard's *Arcadia* (1993)
Martin Steve's *Picasso at the Lapin Agile* (1993)
Snoo Wilson's *Darwin's Flood* (1994)
Paul Godfrey's *The Blue Ball* (1995)
Margaret Edson's *W;t* (1995)
Stephen Poliakoff's *Blinded by the Sun* (1996)
Mark Revenhill's *Faust (Faust Is Dead)* (1997)
Glen Berger's *Great Men of Science, Nos. 21 and 22* (1998)
Timberlake Wertenbaker's *After Darwin* (1998)
Michael Frayn's *Copenhagen* (1998)
Shelagh Stephenson's *An Experiment with an Air Pump* (1998)
Carl Djerassi's *An Immaculate Misconception* (1998)
Arthur Kopit's *Y2K* (1999)
Jeff Stanley's *Tesla's Letters* (1999)
Complicite's *Mnemonic* (1999)
Penny Penniston's *Now Then Again* (2000)
Arthur Giron's *Moving Bodies* (2000)
David Auburn's *Proof* (2000)
Carl Djerassi & Ronald Hoffman's *Oxygen* (2001)
Paul Nullin's *Louis Slotin Sonata* (2001)
Peter Parnell's *QED* (2001)
Nell Dunn's *The Cancer Tales* (2001)
Charlotte Jones's *Humble Boy* (2001)
Caryl Churchill's *A Number* (2002)
Robert Marc Friedman's *Remembering Miss Meitner* (2002)
Jonathan Marc Sherman's *Evolution* (2002)
Matthew Wells' *Schrodinger's Girlfriend* (2002)
Peter Brook & Marie-Helene Estinne's *The Man Who* (2002)
Christopher Hampton's *The Talking Cure* (2002)
Carl Djerassi's *ICSI* (2002)
Liz Duffy Adams' *The Train Play* (2002)
Carl Djerassi & David Pinner's (*Calculus (Newton's Whores*) (2003)
Jacquelyn Reingold's *String Fever* (2003)
Lanford Wilson's *Rain Dance* (2003)
Chiori Miyagawa & James Lattis's *Comet Hunter* (2003)
Lauren Gunderson's *Background* (2003)
Complicite's *The Elephant Vanishes* (2003)
David Pinner's *Newton's Hooke* (2003)
Anna Furse's *Yerma's Eggs* (2003)
Crispin Whittell's *Darwin in Malibu* (2003)
Paul D'Andrea & Jon Klein's *The Einstein Project* (2004)
Erin Lavik's *Galileo Walking among the Stars* (2004)

Timberlake Wertenbaker's *The Laws of Motion* (2004)
Carl Djerassi's *Phallacy* (2004)
Mike Gordon & Paul Broks' *On Ego* (2005)
Carl Djerassi's *Taboos* (2006)
Ira Hauptman's *Partition* (2006)
Crispin Whittell's *Clever Dick* (2006)
Peter Parnell's *Trumpery* (2007)
Complicite's *A Disappearing Number* (2007)
Carey Perloff's *Luminescence Dating* (2007)
Bob Clyman's *Secret Order* (2009)
Deborah Stein's *Bone Portraits* (2009)
Paul Mullin's *The Sequence* (2010)
Sarah Puhl's *In the Next Room (The Vibrator Play*) (2010)
Lauren Gunderson's *Emilie: La Marquise Du Châtelet Defends Her Life Tonight* (2010)
Michael Hollinger's *Tooth and Claw* (2010)
Sarah Treem's *The How and the Why* (2011)
Carl Djerassi's *Insufficiency* (2012)
Lucy Prebble's *The Effect* (2012)
Nick Payne's *Constellation* (2012)
Deborah Stein's *Chimera* (2012)
Itmar Moses's *Completeness* (2013)
Jennifer Haley's *The Nether* (2013)
Adura Onashile's *HeLa* (2013)

Appendix 3

British and American Science Plays Since 1990

Science as Supporting Character

Smith, Tom Morton. *Oppenheimer* (2015) dramatizes the life of the father of the atomic bomb before and after the bombardment of Hiroshima and Nagasaki.

Friedman, Robert Mark. *Transcendence: Einstein, Planck, Kafka vs. Time, Space, and Convention* (2015). Friedman's latest play explores aspects of Einstein's personal life and his revolutionary theories at the time of their creation and initial reception. Friedman also engages emotion and intellect on the stage by telling the story of the strong friendship between Einstein and Max Planck and their attempt to achieve scientific integrity in a decaying society. The play also takes us to 1911 Prague where Einstein and Kafka, both of Jewish origin, meet in a fictional encounter and hope for a world where their dream of being free has come true.

Macmillan, Duncan, and Chris Rapley. *2071* (2014). Directed by Katie Mitchell and written in collaboration with Chris Rapley, professor of Climate Science at University College London, *2071* imagines a dystopian future where humanity's dependence on fossil fuels and creation of greenhouse gases cause drastic climate change.

Sobel, Dava. *And the Sun Stood Still* (2014) is a play that reenacts the historic encounter between Copernicus and the young German mathematician Georg Joachim de Porris, who convinced his fellow scientist to publish the manuscript *On the Revolutions of the*

Heavenly Spheres (1543) that revolutionized understanding of the cosmos.

Stockwell, Richard. *Continuum* (2014) is a play about memory that presents the philosophical conundrum of what happens when we lose some or all of our memories? Are we still ourselves or do we acquire new selves? *Continuum* attempts to answer these questions by focusing on the struggles of Ben, the protagonist, to remember the past after suffering a severe injury to the right frontal lobe of his brain.

Nicholas, Siobhan. *Hanging Hooke* (2014) is inspired by the long-lost "Folio of Robert Hooke", a manuscript discovered and auctioned in 2006 that contains the papers of this 17th-century natural philosopher, architect, and polymath during his time as Curator for the Royal Society.

Graham, James. *Privacy* (2014). Provoked by the revelations of Edward Snowden, former CIA employee, *Privacy* explores how our personal information is being constantly used by governments and corporations, and how this impacts our perception of identity, our future, and our security.

Feehily, Stella. *This May Hurt a Bit* (2014) is a comedy drama inspired by the experiences the playwright's husband had in hospital after suffering three strokes between 2006 and 2007, to discuss the advantages and disadvantages of the NHS.

Fletcher-Wood, Rowena. *Trusting Atoms: The Last Trials of Ludwig Boltzmann* (2014) features the passion and sufferings of this 19th-century Austrian physicist in his struggle to save the theory of atoms, his equation and so his career.

Fritz, James. *Four Minutes Twelve Seconds* (2013). A play that explores the dangers of electronic communication for young people.

Brody, Alan. *Operation Epsilon* (2013). As World War II is approaching its end, the British and Americans have imprisoned 10 of the most important German scientists in a fully bugged house to find out how close Germany is to building an atomic bomb.

Hanth, Lucas. *Isaac's Eyes* (2013) is set in 1650 but written in contemporary language, and features the young Edison getting involved in a battle of intellects and egos with Robert Hooke.

Haley, Jennifer. *The Nether* (2013) explores the devastating consequences of the future evolution of the Internet.

Moses, Itamar. *Completeness* (2013). A play about a computer scientist and a molecular biologist whose scientific predilections result in romantic entanglements.

Alda, Alan. *Radiance: The Passion of Marie Curie* (2013) details the challenges that Marie Curie had to face in pursuing her career as a scientist in a society in which it was virtually impossible for women to take important roles in academic or public life.

Alexandratos, Jonathan. *Chain Reaction* (2012). A dark comedy that follows the efforts of the scientists working on the Manhattan project during World War II, particularly Robert Oppenheimer, to build the weapon that will end the war.

Prebble, Lucy. *The Effect* (2012) focuses on a clinical trial for a new antidepressant.

Treem, Sarah. *The How and the Why* (2011) deals with the clashes between two women biologists, one an established leader in the field and one who is just beginning, over the biological advantages of menstruation. Through these scientific clashes, the workings of science and its impact on the lives of women scientists are also explored.

Giron, Arthur. *Emilie's Voltaire* (2010). A dramatic comedy that explores the sexually-driven intellectually-fuelled relationship between two 18th-century scientists, Emilie Marquise De Chatelet and Francois-Marie Arouet (Voltaire).

Hollinger, Michael. *Tooth and Claw* (2010) focuses on attempts to preserve a species of endangered giant tortoises on the Galápagos Islands.

Gunderson, Lauren. *Emilie: La Marquise Du Châtelet Defends Her Life Tonight* (2010). A play about the love life and scientific achievements of the 18th-century physicist Emilie De Chatelet.

Ruhl, Sarah. *In the Next Room* (*The Vibrator Play*) (2010) explores the early history of the vibrator, when doctors utilized it as a medical device to help women reach orgasm as a treatment for hysteria.

Mullin, Paul. *The Sequence* (2010) focuses on the competition between two brilliant scientists to be the first to map the human genome.

Clyman, Bob. *Secret Order* (2009). Set in a prestigious Manhattan cancer institute, the play examines the power plays and strategic deception characterizing the scientific research.

Baxter Craig. Let Newton Be (2009) is a play entirely constructed based on the letters to, from, or about Newton and focuses on the collision between his religious and scientific beliefs.

Stein, Deborah. *Bone Portraits* (2009) illustrates America's fascination with x-ray technology in the early 19th century and explores its hazardous impacts, especially on the men who were operating the cameras.

Ziegler, Anna. *Photograph 51* (2008) dramatizes the working life of Rosalind Franklin and her involvement in the discovery of DNA.

Parnell, Peter. *Trumpery* (2007) enacts the conflict between the two originators of the theory of evolution, Charles Darwin and Alfred Russell Wallace.

Perloff, Carey. *Luminescence Dating* (2007). A play that focuses on three archaeologists' quest for a lost 4th-century BCE statue of the goddess Aphrodite.

Walat, Kathryn. *Victoria Martin: Math Team Queen* (2007). This play features a popular high school girl who is placed in an all-boys maths team by the principal. To everyone's surprise, it turns out that not only is she good at maths, but she can also teach the guys what it means to be human.

Hoffmann, Roald. *Should've* (2007) focuses on the impact of a chemist's suicide (due to feeling guilty for putting an easy way to make a neurotoxin into the hands of terrorists) on his daughter, his lover, and his second wife.

Sorkhin, Aaron. *The Farnsworth Invention* (2007). A stage play inspired by the invention of television signal transmission.

Groff, Rinne. *The Ruby Sunrise* (2006) tells the story of Ruby, a self-taught scientist who created the very first prototype of the television, and dramatizes the course of his invention from the early stages of idealism to the later stages when his dream of television bringing world peace completely fails.

Wesker, Arnold. *Longitude* (2006) is about John Harrison, who in the early 18th century solved the problem of finding longitude by inventing a clock that could run accurately at sea.

Whittell, Crispin. *Clever Dick* (2006). Two months before the bombardment of Hiroshima and Nagasaki, Richard Feynman makes a wrong turn out of Albuquerque and finds himself involved in a series of fictional events.

Hauptman, Ira. *Partition* (2006) focuses on the collaboration between two of the most renowned mathematicians of the twentieth century G.H. Hardy and Srinivasa Ramanujan.

Perkowitz, Sidney. *Glory Enough* (2005). A stage play about Rosalind Franklin.

Wertenbaker, Timberlake. *The Laws of Motion* (2004) features Galileo's illegitimate daughter, Marria Celeste, who was committed to a Florentine convent of the Poor Clares. The dramatic crises stems from Galileo's renunciation in 1633.

Cook, Peter and William Lanouette. *Uranium+Peaches* (2004) explores the tension between science and politics by focusing on the confrontation between Einstein's protégé, Leo Szilard, and Truman's mentor, Jimmy Byrnes.

Lavik, Erin. *Galileo Walking among the Stars* (2004). Three scientists, Galileo, Johannes Kepler, and Thomas Harriet are brought back to life to build a spaceship to be able to walk among the stars.

D'Andrea, Paul and Jon Klein. *The Einstein Project* (2004). A play about the birth of the atomic bomb and the role Einstein and other German physicists including Werner Heisenberg played in it.

Gunderson, Lauren. *Wide World* (2004) dramatizes the 1804 meeting between Thomas Jefferson and the Prussian geographer Alexander Von Humboldt.

Djerassi, Carl. *Phallacy* (2004). Inspired by actual events, *Phallacy* focuses on the conflict between Regina, a top art historian whose career is invested in an ancient statue thought to be a Roman original, and Rex, a chemist whose dating analysis of the artwork has shown it to be merely a 16th-century cast.

Gunderson, Lauren. *Leap* (2004). Two young playful sisters, Brightman and Maria, become Newton's source of inspiration for his great discoveries by offering him their creativity and curiosity in exchange for his participation in games.

Wilson, Snoo. *Lovesong of the Electric Bear* (2003) juxtaposes Alan Turing's mathematical gift that made him the code-breaking hero of World War II with his homosexuality, which led him to betrayal by the same establishment whose victory was entirely dependent upon him.

Jones, Rolin. *The Intelligent Design of Jenny Chow* (2003) features a 22-year-old Californian genius with agoraphobia and obsessive-compulsive disorder who decides to find and meet her biological mother. Being scared of stepping outside her door, she decides to create a robot replica of herself and sends it around the world.

Nachtmann, Rita. *The Thread of Life* (2003). A play about Rosalind Franklin's role in discovering DNA.

Magnus, Bryan. *World Set Free* (2003) deals with the complexities of producing the first controlled nuclear chain reaction and the top-secret experiments that led to it. It also examines the impact of this secrecy on the lives of the people involved.

Whittell, Crispin. *Darwin in Malibu* (2003) explores the relation between science and ethics by bringing Darwin, Thomas Huxley, and Samuel Wilberforce, the bishop of Oxford, back to life, over a hundred years after their deaths.

Pinner, David. *Newton' Hooke* (2003) dramatizes the battle between Newton and Robert Hooke in the name of science.

Djerassi, Carl. *Calculus* (*Newton's Whores*) (2003) is about Newton and the German mathematician Gottfried Leibnitz's dispute over who first invented Calculus.

Miyagawa, Chiori, and James Lattis. *Comet Hunter* (2003) explores the life and scientific achievements of the first recognized female astronomer in history, Caroline Herschel.

Wilson, Lanford. *Rain Dance* (2003) is about the nuclear bomb testing in Los Alamos during the final days of World War II.

Horovitz, Israel. *Promises.com* (2003). On the edge of a revolutionary discovery in cancer treatment, a dedicated Jewish-liberal biologist has to choose between altruism and financial success.

Hampton, Christopher. *The Talking Cure* (2002) focuses on the early years of Jung and his pivotal relationship with one of his patients who later became a psychoanalyst, Sabina Spielrein.

Perkowitz, Sidney. *Friedmann's Balloon* (2002) is about Aleksander Friedmann, who in the 1920s found an error in Einstein's general theory of relativity.

Sherman, Jonathan Mark. *Evolution* (2002) explores the impact of technology within the context of pop-culture and the entertainment industry.

Friedeman, Robert Mark. *Remembering Miss Meitner* (2002) brings three physicists, Lise Meitner, Otto Hahn, and Manne Siegbahn, to a present-day stage to answer the question of why, despite her significant contribution to the discovery of nuclear fission, Meitner did not share in the 1944 Nobel Prize for Chemistry.

Churchill, Caryl. *A Number* (2002) addresses the subject of human identity and public debates over the ethics of cloning, structured around the conflict between a father and his sons, two of whom are clones of the first.

Frontczak Susan Marie. *Manya* (2002). A one-woman drama that explores the life, triumphs, and struggles of Marie Curie.

Burns, Lizzie. *Autodestruct: The Ultimate Cure for Cancer* (2001)**.** Written by an Oxford graduate in molecular cell biology, *Autodestruct* features a scientist who clones his way to immortality.

Dunn, Nell. *Cancer Tales* (2001). This play tells five personal histories of the pain, disappointment, hope, and love of people whose lives have been affected by cancer.

Parnell, Peter. *QED* (2001) chronicles part of a day in the life of Richard Feynman, covering topics ranging from his wife's death to the Manhattan project to his own struggle with cancer.

Mullin, Paul. *The Louis Slotin Sonata* (2001) enacts the last 9 days of the life of Canadian physicist and chemist Louis Slotin who died of acute radiation syndrome during the Manhattan Project.

Penhall, Joe. *Blue/Orange* (2001). Set in a London psychiatric hospital, Penhall focuses on the clashes between two psychiatrists over the psychological state of a patient named Christophe who claims to be the son of an African dictator.

Auburn, David. *Proof* (2000) dramatizes the link between mathematical genius and mental illness by focusing on a mathematician's attempt to prove the authorship of a mathematical proof.

Groff, Rinne. *The Five Hysterical Girls Theorem* (2000) tells the story of prominent number theorist Moses Vazsonyi, who fears that he is losing his skills in the intellectually demanding world of prime number theory.

Wellman, Mac. *Hypatia* (*The Divine Algebra*) (2000). The 5th-century mathematician Hypatia begins a journey through time from the 8th century to the 20th century where she hopes to exchange the number zero for an American girl's bicycle.

Giron, Arthur. *Moving Bodies* (2000) dramatizes the biography of Richard Feynman.

McGrath, Tom. *Safe Delivery* (1999) explores ethical quandaries raised by genetic studies.

Stanley, Jeffry. *Tesla's letters* (1999). A young American PhD student flies to Belgrade to research the life of Edison's biggest rival, Nikola Tesla. Attempting to gain access to a collection of Tesla's personal letters housed at the Nikola Tesla museum, she travels to Tesla's birthplace in Croatia, only to witness Serbian infliction of death and destruction on Croatians.

Kopit, Arthur. *Y2K* (1999) touches on the dangers of privacy invasion in an age of computers and technology.

Landau, Tina. *Space* (1998) is based on the life of the American neuropsychiatrist Allen Saunders and his researches on people who believed they gave been abducted by aliens.

Giron, Arthur. *Flight* (1998) explores the lives of the Wright family.

Irvine, Todd. *Notes on the Uncertainty Principle* (1998) dramatizes the uncertainties surrounding Heisenberg's role in the invention of atomic bomb.

Stephenson, Shelagh. *An Experiment With an Air Pump* (1998) examines the moral dimensions of scientific research across two centuries, in 1799 and 1999, by focusing on the dissection of dead bodies for the sake of medical research and the human genome project.

Berger, Glen. *Great Men of Science Nos. 21 & 22* (1998) focuses on the serious attempts of two little-known scientists, Jacques de Vaucanson and Lazzarro de

Spallanzani, to advance humanity's understanding of life, and the complex and apparently intelligent design of the universe, at the height of the Age of Enlightenment.

Ravenhill, Mark. *Faust Is Dead* (1997) travels through the world of virtual reality to explore the negative consequences of technology.

Poliakoff, Stephan. *Blinded by the Sun* (1996) details how the pressure to succeed can become a source of conflict in the world of science, by telling the story of the rivalry among three scientists in a chemistry department.

Simms, Willard. *Einstein: A Stage Portrait.* (1996). A one-man show about the life of Albert Einstein and his struggles to hold forth music, science, fame, and the true meaning of life.

Godfrey, Paul. *Blue Ball* (1995) is an imaginative investigation of the experience of space travel.

Edson, Margaret. *W;t* (1995) features a John Donne scholar, Professor Vivian Bearing, dying from ovarian cancer. As her disease and its painful treatment progress, Vivian starts reflecting on her past, asking questions about what she did wrong and what will happen next.

Wilson, Snoo. *Darwin's Flood* (1994). On the night of his death, Darwin is visited by Nietzsche, Jesus Christ, and Mary Magdalene, to show him that God exists and the theory of evolution does not.

Martin, Steve. *Picasso at the Lapin Aglie* (1993) features Albert Einstein and Pablo Picasso meeting in a bar called Lapin Aglie in Paris, debating the value of genius and talent.

Kushner. Tony. *Angels in America: A Gay Fantasia on National Themes* (2003). A symbolic metaphorical examination of AIDS and homosexuality in America in 1980s.

Feldshuh, David. *Miss Ever's Boys* (1992) dramatizes the secret medical experiments conducted by the Federal Government on African Americans between the years of 1932 and 1972.

Science as Leading Character

Payne, Nick. *Elegy* (2016) imagines a near future in which radical advances in medical science has made it possible to cure a degenerative brain condition by removing a part of the brain and with it decades' worth of memories. In effect that means loosing a part of one's life and therefore identity. Through the skillful use of reverse chronology, the play reestablishes a relationship that has been destroyed by amnesia.

Baxter, Craig. *Pictures of You* (2015) is about mental imagery, emotion, and the treatment of bipolar disorder. Written in collaboration with psychiatrist Martina Di Simplicio, *Pictures of You* tells the story of two old friends who reunite after many years apart to discuss the challenge of remembering the past and picturing the future.

Stoppard, Tom. *The Hard Problem* (2015) explores the problem of consciousness and discusses the differences between 'the mind' and 'the brain'.

Stephens, Simon. *Heisenberg* (2015). Stephens takes the theory of Uncertainty in quantum physics and brings it to the lives of the two protagonists of the play who accidentally meet in a train station in London, an encounter that sets them on a life-changing path.

Gunderson, Lauren. *Silent Sky* (2014) explores the life and scientific achievements of the 19th-century astronomer, Henrietta Leavitt. In the play, the protagonist's need to know where she is becomes a part of her scientific and personal goal.

Payne, Nick. *Incognito* (2014) explores the human brain and the close connection between memory and the human sense of selfhood. In the play, more than twenty roles are played by only four actors, and the action ranges from 1950 to the present.

Gunderson, Lauren. *By and By* (2013) deals with cloning and losing one's love and wanting to replace them.

Baxter, Craig. *Somniloguy* (2013). Written in collaboration with Richard Horner, professor of medicine and psychology, *Somniloguy* explores sleeping disorders and the damage they cause to human interactions.

Lewenstein, Rose. *Game of Life* (2012) uses the mathematical phenomenon of emergence to explore the relationship between life and death and thoughts and feelings.

Payne, Nick. *Constellations* (2012). A play that enacts the theory of the multiverse in quantum theory by telling the love story of a beekeeper called Roland and an attractive astrophysicist called Marianne.

Djerassi, Carl. *Insufficiency* (2012) deals with the science of bubbleology and is a parody of academic one-upmanship over a battle for tenure at an American university.

Baxter, Craig. *The Altruists* (2012) focuses on the lives and revolutionary discoveries of three evolutionary biologists, George Price, Bill Hamilton and John Maynard Smith, on the mathematical and evolutionary basis of altruism. The play tries to answer questions such as how should we live and what are the benefits of the choices we make?

Baxter, Craig. *Re:Design* (2008) focuses on the correspondence between Charles Darwin and Harvard botanist Asa Gray in an attempt to reunite orthodox Christian views with Darwin's theory of evolution by natural selection.

Djerassi, Carl. *Taboos* (2006) explores the implications of modern fertility techniques.

Medley, Cassandra. *Relativity* (2006). Clair is a black woman who runs an organization dedicated to 'melanin science', the theory that proves black people are genetically superior to white people. Research by her daughter, a molecular geneticist, however, proves otherwise and threatens to ruin the mother-daughter relationship.

Gunderson, Lauren. *Mass* (2005). A one-woman play that focuses on the life of Lieserl, the lost daughter of Einstein, enacting her search for her father with reference to the theory of relativity.

Gunderson, Lauren. *Background* (2003). Mimicking the study of the origins of universe, Gunderson explores the life of cosmologist Dr Ralph Alpher, who was the first to provide the mathematical proof of the existence of Cosmic Background Radiation.

Reingold, Jacquelyn. *String Fever* (2003). A romantic comedy that explores the failure of modern relationships, with reference to artificial insemination and the scientific Theory of Everything.

Wells, Mathew. *Schrödinger's Girlfriend* (2002). A burlesque romantic comedy that dramatizes Schrödinger's attempt to come up with an easy explanation for the logical absurdities and uncertainties that govern the behavior of subatomic elements.

Adams, Liz Duffy. *The Reckless Ruthless Brutal Charge Of It (The Train Play)* (2002). A comic threnody in which the Earth Goddess, a twelve-year old girl with a mysterious power to manipulate time, and an unraveling physicist, meet on a late-night train.

Djerassi, Carl. *ICSI* (2002) explores the science of direct-injection fertilization and the ethical issues connected with it.

Jones, Charlotte. *Humble Boy* (2001). Inspired by Hamlet and superstring theory, the play tells the story of a young theoretical astrophysicist from Cambridge who returns home to attend his father's funeral. Once there, he realizes that his mother, Flora, is planning to marry George, a man with whom she has been having an affair for many years, which becomes the source of the tension in the play.

Djerassi, Carl. *Oxygen* (2001) explores the questions of 'what is discovery?' and 'why is it important to be first?' by focusing on the controversies surrounding the discovery of oxygen.

Penniston, Penny. *Now Then Again* (2000) tells the story of two physicists, Henry and Jinny, who find each other in the future within the context of quantum mechanics.

Frayn, Michael. *Copenhagen* (1998) uses the Copenhagen interpretation of quantum mechanics as a metaphor for the inaccessibility of human intentions.

Djerassi, Carl. *An Immaculate Misconception* (1998) focuses on the ethical issues surrounding scientific research in an age of reproductive technology and genetic cloning.

Wertenbaker, Timberlake. *After Darwin* (1998) dramatizes the theory of evolution and the struggle for survival in the form of a play-within-a-play.

Stoppard, Tom. *Arcadia* (1993) attends to a wide range of subjects including the second law of thermodynamics, chaos theory, fractals, and algorithms, to explore the nature of historical evidence and truth.

Science As Director

Basloe, Frank. *Please Continue* (2016). Capturing the personal side of human research, this theatre piece explores the ethical questions raised by Stanley Milgram's infamous social psychology experiments on obedience in the 1960s.

Complicite (in association with HOME Manchester). *A Pacifist's Guide to the War on Cancer* (2016). A musical that confronts the highs and lows of life with cancer.

Long, Adam. *Miss Atomic Bomb* (2016). A musical comedy inspired by the real-life beauty pageants held to celebrate atomic bomb testing outside Las Vegas in the early Fifties, before the real dangers of fallout and radiation were known.

Basloe, Frank. *Please Continue* (2016). Capturing the personal side of human research, this theatre piece explores the ethical questions raised by Stanley Milgram's infamous social psychology experiments on obedience in the 1960s.

Idle Emotion. *That Is All You Need to Know* (2015). A piece of visual theatre that tells the story of the remarkable collaboration between Alan Turing and Gordon Welchman on cracking the enigma code.

Hinton, John. *The Element in the Room* (2015). A musical comedy about the life and death of Marie Curie.

Islington Community Theatre. *Brainstorm* (2015). Drawn from the cast's experiences of going through the changes happening in their brains as teenagers, Islington Community Theatre explores the workings of the adolescent brain.

Metta Theatre. *Mouthful* (2015). A dark comedy produced as a result of collaboration between scientists and theatre directors, which discusses the global food crisis.

Curious Directive. *Pioneer* (2014) is a multi-layered thriller set in the near future, and concerns humanity's attempt to establish a settlement on Mars.

Macmillan, Duncan. *The Forbidden Zone* (2014). A multimedia show about chemical weapons in World War I and the story of their inventor Fritz Haber.

Watts, Murray. *Mr. Darwin's Tree* (2014). A one-man play that focuses on the struggles that the founder of the theory of evolution faced as a result of having lost his faith after the death of his daughter, Annie.

Curious Directive. *The Kindness of Stranger* (2014) is a theatre piece about the future of the NHS. Lisa, a young paramedic on her first day on the front line of the NHS ambulance service, comes into conflict with her driver, who believes the NHS's useful days are over.

Hinton, John. *Albert Einstein: Relatively Speaking* (2013). Einstein is desperately trying to give a lecture about his theories of relativity at Princeton University when the play suddenly move forward in time to see the consequences of his discoveries, namely the birth of the atomic bomb.

Adura Onashile, *HeLa* (2013). A solo show that draws on the true-life story of Henrietta Lacks, an African-American woman whose cells have been used since the 1950s in medical research, to explore the problems of genetic identity and ethical debates about human tissue research and ownership.

Curious Directive. *In The Image of You* (2013) focuses on the cutting edge of genetics and searches for its origins by dramatizing the life of Rosalind Franklin, the true discoverer of the structure of DNA.

Mermikides, Alex. *Bloodlines* (2013) discusses different ways in which the human body is interpreted in arts and medicine by following a young man through his experiences of cancer and the pain and fatigue of intense chemotherapy.

Fuel Theatre. *Body Pods* (2013). In 2012 Fuel Theatre created a series of twelve podcasts from different parts of the human body, each made as a collaboration between a scientist and an artist.

Bardsley, Julia. *Medea_DARK/ROOM* (2013). Working through the persona of Medea, Bardsley explores the ideas of the neurobiology of creativity and the performative physics of eroticism.

Emmott, Stephan. Ten Billion (2013). Directed by Katie Mitchell, the theatre piece discusses the impact of over-population on the environment.

Du Sautoy, Marcus, and Victoria Gould. *X&Y* (2013). Written and performed by an Oxford professor of mathematics, Marcus du Sautoy, and the actress and mathematician Victoria Gould, *X&Y* uses mathematics to tackle issues such as the shape of the universe, the nature of reality, and the concept of infinity.

Naylor, Hattie (in collaboration with Sound and Fury). *Going Dark* (2012) features an astronomer who is losing his sight, and who discovers that in order to understand the universe he needs another kind of vision.

Curious Detective. *After the Rainfall* (2012) uses the chambers of an ant colony as a metaphor to explore different chapters of human history and examines the way in which human ideas spread, with reference to ants' system of communication.

Stein, Deborah. *Chimera* (2012). An esteemed geneticist and a mother, Jennifer Samuels learns she possesses two sets of DNA, one hers and one her unborn twin's whom she absorbed in the womb. Jennifer's eggs –and a few other parts of her body – carry her sister's DNA, meaning her son is genetically her nephew. Shaken by the discovery, she starts to question who she really is: herself? Her twin? Or both?

Nicholas, Siobhán. *Stella* (2012). Jessica Bell, a present-day radio astronomer, and the 18th-century German astronomer Caroline Herschel reside for six days in the same house in Bath. Despite the fact that both women can perfectly map their position in the

universe, they both struggle to place themselves in the world.

Fevered Sleep. *Stilled* (2012). A durational dance (performed for between 3 to 12 hours) and photographic installation inspired by the scientific process of x-ray crystallography.

Fevered Sleep. *Written with Light* (2012). Part performance, part installation, *Written with Light* focuses on the ability of photographs to act as visual stories, by featuring a young woman with impaired memory who can only piece her life together through photographs.

Unlimited Theatre. *The Ethics of Progress* (2012). A theatre piece about the actual, philosophical, religious, ethical, and political impact of quantum physics.

Unlimited Theatre. *The Noise* (2012). Focusing on the inhabitants of the always-full-of-noises island of Whitley in the south Atlantic, Unlimited Theatre explores the cognitive effects of sound.

Fuel Theatre. *Autobiographer* (2012) explores dementia, a disorder of the mental processes caused by brain disease or injury, by taking us to a journey through Flora's broken thoughts, using the actual last remembered moments of the life of someone suffering from the disease.

Curious Directive. *Your Last Breath* (2012). Inspired by the true story of Anna, a young radiologist and skier who froze under the ice for 40 minutes after a skiing accident in Norway, but was brought back to life in a medical miracle, *Your Last Breath* interweaves Anna's story with three other distinct stories across the centuries: in 1876,

the story of Christopher, who maps the uncharted mountains of Norway for the first time; in 2015, Freija, a successful businesswoman who travels to Norway to scatter her father's ashes; and in 2036, Nicholas, Anna's son, who explains the importance of Anna's story not just for him but also for the whole world.

Schatz, Matt. *The Tallest Building in the Word* (2011). A theatre piece about the World Trade Center's structural design.

White, Sharr. *The Other Place* (2011). The play focuses on the complexities of the psychological state of a successful neurologist whose life seems to be coming unhinged; she is convinced she has brain cancer, her husband has filed for divorce, and her daughter has run away from home to be with an older man.

Curious Directive. *Exoplanets* (2011). A theatre piece performed under the night sky combining a DJ, movement, video and astronomy, to create a new vision of the solar system and planets, and what are known to be exoplanets.

Curious Directive. *Drift: Photo 51* (2010). The story of Rosalind Franklin's capturing of *Photo 51*, which suggested the structure of DNA, in 1947 runs parallel to the story of a young ballerina who questions her genetic heritage and decides to rewrites her future.

Third Angle. *Technology* (2009). "Inspired by a speech from Parts For Machines That Do Things, Alex improvises a monologue explaining all of the technology -simple and complex- that he encounters on his way in to work. Not satisfied with that, he then tries to explain gravity and why clocks run at different speeds depending on how fast they

travel"[42].

Third Angel. *A Perfect Circle* (2009). "A female human being performs a ritual: an attempt to describe a circle and an attempt to describe the world as if all you could see of it were the series of images carried on the Voyager satellites, the two furthest-travelled human-made objects from the Earth"[43].

Pit. *A Stroke of Genius* (2009). A dark comedy about Darwinism, genetics, sperm, and the future of humankind.

Reckless Sleeper. *Schrodinger's Box* (2009). A theatre piece about Schrödinger's Nobel Prize-winning theory of a box in which a cat can be simultaneously dead and alive. This theory was used as a metaphor to clarify the complementarity and uncertainty principle in quantum mechanics.

Curious Directive. *Return to the Silence* (2008) tells the story of the neurologist Doctor Jill Taylor whose stroke enabled her to study her own brain from the inside, as result of which she makes a series of life-changing discoveries about her perception of the world.

Gordon, Mike and Paul Broks. *On Emotion* (2008). The theatre practitioner Mick Gordon and neuropsychologist Paul Broks enact a concept called 'cognitive dissonance', which refers to a state of having inconsistent thoughts and beliefs as a result of the opposition between emotional impulses and rational thoughts.

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[42] "Technology." *Third Angel Archive*. Third Angel, n.d. Web. 13 May 2016.
[43] "A Perfect Circle." *Third Angle Blog*. 3.Sep. 2009. Web. 13 May 2016.

Hinton, John. *The Origins of Species* (2008). Having put aside his study on the origins of species, Charles Darwin is hard at work on his new book on barnacles. Correspondence with a fellow naturalist, Alfred Wallace, who puts forth almost exactly the same theory of evolution, forces Darwin to finish his work in spite of his fear over the dispute it would cause in the Christian society of the time.

Clod Ensemble. *Performing Medicine* (2007). A program of courses, workshops, and events, which were designed to help medical students with their studies through the medium of art and performance.

Complicite. *A Disappearing Number* (2007) enacts the collaboration in the 1910s between G.H. Hardy and Srinivasa Ramanujan.

Zellnik, David. *Serendib* (2007). A hybrid of drama and puppetry, *Serendib* examines the thin line between nature and nurture, and explores the differences between modern humans and primates.

Adams, John. *Doctor Atomic* (2005). An opera about America's secret and successful attempt to build the first atomic bomb.

Lawrence, Jeremy. *Albert in Wonderland: A Fantasia on Einstein* (2005). The appearance of a woman who claims to be Einstein's daughter causes him to time travel in his life, which eventually reveals personal chaos in the life of the scientist, whose life was devoted to finding a universal order.

Gordon, Mike and Paul Broks. *On Ego* (2005) is an exploration of identity within the context of neuropsychology.

Daisey, Mike. *Monopoly* (2005) details the rivalry between Edison and Nikola Tesla.

Third Angle. *Hurrysickness* (2004). "A performance lecture exploring the science and history of time and time pressure. The audience are invited to contribute to the research by participating in a few of experiments - multitasking at its most entertaining". [44]

Parker, Norman. *Feynman's lives* (2003). A solo tribute to Richard Feynman's life and wisdom.

Complicite. *The Elephant vanishes* (2003). Inspired by the short stories of Haruki Murakami, the theatre piece explores the impact of technology on people's lives in a Japanese setting.

Furse, Anna. *Yerma's Eggs* (2003). A performance piece about aging and reduced fertility.

Zimmerman, Mary. *The Notebooks of Leonardo Da Vinci* (2003). A theatre piece with music, dance, and acrobatics that delves into the mind of Da Vinci by using his scientific theories, thoughts, and instructions for artistic discovery and presentation.

[44] "Hurrysickness." *Third Angle Archive*. Third Angel, n.d. Web. 13 May 2016.

Barrow, John (in collaboration with the Italian theatre director Luca Ronconi) *Infinities* (2002). Written by a mathematical scientist, the play is made up of five scenes touching on strange paradoxes and the mysteries of infinity.

Perkowitz, Sidney. *Albert and Isadora* (2002). A performance-dance piece featuring an imaginary meeting between Einstein and dancer Isadora Duncan in which they talk, flirt, and share their views about the universe.

Brook, Peter, and Marie-Helene Estienne. *The Man Who* (2002). A theatre piece inspired by Oliver Sacks' *The Man Who Mistook His Wife for a Hat* (1985), a collection of case histories of some of his neurologically impaired patients.

Glass, Philip, and Mary Zimmerman. *Galileo Galilei* (2002). An opera that explores the life of Galileo based on his letters to and from his family.

Reich, Steve, and Beryl Korot. *Three Tales* (2002). A video-opera in three acts that responds to modern technological achievements such as the explosion of the Hindenburg, nuclear testing on Bikini Atoll, and the cloning of Dolly the sheep.

Speier, Susnna. *Calabi Yau* (2002) is based on physicist Brian Greene's best-seller *The Elegant Universe* (1999).

Shiflett, Melissa. *Dora, the Opera* (2002) is inspired by the story of an 18-year-old patient of Sigmund Freud's, Ida Bauer, whom he called Dora.

Unlimited Theatre. *Neutrino* (2001) consists of two narrative strands, one featuring a university professor giving a lecture on particle physics and the other on two groups of people facing unexpected events.

Mac Low, Clarinda, and James Hannaham. *The Division of Memory* (2001) focuses on racial history in America by enacting the final moments of the life of an African American biologist.

Zimet, Paul, and Ellen Meadow. *Star Massager* (2000). An opera that focuses on the life and discoveries of Galileo.

Smith, Deavere. *Untitled* (2000). A one-woman show about the resilience and vulnerability of the human body.

Lessner, Joanne Sydney, and Joshua Eosenblum. *Fermat's Last Tango* (2000). A musical inspired by the life of Andrew Wiles, a Princeton University professor who proved the 350-year-old problem of Fermat's last theorem.

Complicite. *Mnemonic* (1999) A theatre piece that uses several interconnected stories to explore the concept of memory.

Forkbeard. *The Brain* (1999). Written in collaboration with neuroscientist Emil Toescu, the performance features a scientist, Doctor Bucephalus Grimes, who travels into his own head through the jumble of his neurons and memories.

Tony Harrison. *Square Rounds* (1992). A theatre piece written in verse and played by a cast of women, *Square Rounds* explores the double-edged nature of scientific progress with reference to artificial fertilizers and TNT.

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Haley, Jennifer. *The Nether*. London: Faber & Faber, 2014. Kindle file.

Hampton, Christopher. *The Talking Cure*. London: Faber & Faber, 2002. Print.

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Miyagawa, Chiori, and James Lattis. "Comet Hunter." *Thousands Years Waiting and Other Plays,* written by Chiori Miyagawa. New York: Seagull Books, 2012. Print.

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